PHYSICAL ACTIVITY AND COGNITIVE FUNCTION OUTCOMES IN OLDER ADULTS

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Chapter 1: Introduction

Statement of the Problem. Dementia is a disease most often characterized by a chronic and progressive onset of deficiencies in cognitive functions including learning, scheduling, inhibition and memory tasks (Wortmann), 2012). While the specific causes of the disease have not yet been identified, evidence suggests the disease to be linked to an increased incidence of all-cause mortality risk factors associated with aging (Newman et al., 2007; Whitmer et al., 2005). Diabetes, midlife hypertension, obesity, depression, physical inactivity, smoking and lower education are the most commonly identified modifiable risk factors associated with increased dementia incidence and prevalence (Barnes & Yaffe, 2011; Eggermont, 2009). Older adults experience the highest rates of dementia disease incidence and prevalence because of the greater likelihood of living with these risk factors (Wortmann, 2012). Physical activity (PA) has been shown to have a strong inverse dose-response relationship with all aforementioned risk factors (Ferrucci et al., 1999; Haskell et al., 2007; Kesaniemi et al., 2001; Tanascescu et al., 2002). Despite this, older adults remain the most physically inactive cohort of any group.

The American College of Sports Medicine (ACSM) recognizes the benefit of PA on health and its inverse relationship with many comorbidity risk factors (Haskell et al., 2007). Furthermore, the ACSM has identified 150 minutes of moderate or 60 minutes of vigorous PA or a combination of moderate to vigorous PA (MVPA) to be the threshold for receiving health and fitness benefits for both healthy younger and older adults (Haskell et al., 2007; Nelson et al., 2007). Nonetheless, research shows only 2.5% of older adults are meeting national guidelines outlined by the ACSM and 62% achieve none (Harris, 2009). Dose-response guidelines have been well established with strong evidence suggesting improvements of all-cause mortality, cardiorespiratory, metabolic, weight management, musculoskeletal and functional health risk factors.

Although evidence for the aforementioned chronic disease risk factors is strong, evidence for the inverse relationship between PA and cognitive health remains weak (Physical Activity Guidelines Advisory Committee Report, 2008). Weak relationships are in large part attributed to a relatively small body of literature that have examined correlation and causal relationships between the two variables (Etnier & Chang, 2009). Diminished cognitive health and well-being present a considerable public health concern as increasing prevalence and incidence of cognitive diseases such as dementia and Alzheimer's lead to subsequently growing associated mortality rates (Wortmann, 2012).

Annual healthcare care costs complicate the disease burden. As of 2010, the World Health Organization (WHO) estimated total worldwide costs of dementia to be 604 billion dollars. With a globally aging population, prevalence and incidence projections suggest that the total number of people with dementia will rise from 35.6 million in 2010 to 65.7 million by 2030. These projections further suggest this number will again double to 115.4 million by the year 2050 (Wortmann, 2012). With 7.7 million new cases of dementia diagnosed each year, it is critical to pursue meaningful prevention and treatment options.

Only in the last decade have longitudinal studies and meta-analyses identifying potential modifiable risk factors for dementia prevention emerged (Etnier & Chang, 2009; Kramer, 2006; Sofi, 2010). Due to the infancy of this research, primary prevention recommendations have not yet been established. Evidence supporting the inverse dose-response between PA and all-cause mortality stands as the best proposed deterrent (Laurin, 2001; Ku, Stevinson & Chen, 2012). Additionally, some research has indicated that increases of PA intensity, frequency and duration could offer further benefits to decreasing dementia risk (Colcombe & Kramer, 2003). Although emerging research suggests a potential dose-response relationship between PA and cognitive function lacking random control trial (RCT) studies prevent such claims. It is then necessary to identify PA's role as a valid and feasible primary prevention option so RCT designs can be developed (Barnes, Whitmer & Yaffe, 2007).

Findings from initial PA intervention research (Spirduso, 1975) suggest that cognitive function outcomes among physically active older adults are significantly higher when compared to less physically active controls. The original cognitive construct was derived from this earlier study which measured response time. The idea that the central nervous system could benefit from PA was developed from results indicating improved task response times with increased PA. This relationship has since been confirmed by subsequent research in multiple areas of cognitive performance (Boucard et al., 2012; Colcombe & Kramer, 2003; Van Gelder, 2004). While the results from some empirical studies have been equivocal, outcomes from meta-analyses suggest a decreased risk of dementia among physically active individuals (Colcombe & Kramer, 2003; Etnier & Chang, 2009; Kramer, 2006; Sofi, 2010).

Although meta-analyses have identified a positive correlation between increased PA and improved cognitive health, methodological limitations, inconsistent use of psychological terminology and varying methods for monitoring PA have made interpretation of these results difficult. Therefore, to date, little is known about the direct influence of PA on cognitive function. In fact conflicting approaches from PA specialists, exercise physiologists, and neuropsychologists examining these effects have left gaps in practice that have proven difficult to fill (Barnes, Whitmer & Yaffe, 2007). Consequently, substantial challenge exists for researchers in adapting feasible and interpretable PA assessment techniques (Harris, 2009; Grant et al., 2010) as well as valid cognitive performance measures for older adults (Golden & Freshwater, 2002, Salthouse, 2005).

Few studies have assessed PA and cognitive function by use of objectively measured PA devices (accelerometers) and even fewer have compared these PA variables to multiple cognitive performance task outcomes (Barnes et al., 2007; Boucard et al., 2012). To date, only one intervention study has objectively assessed PA and cognitive performance outcomes in older adults (Lautenschlager et al., 2008). In this study, older adults (50 years and older; N=138) were randomized to intent-to-treat and control groups. Intent-to-treat participants received a 24-week PA intervention. In both groups PA was monitored using accelerometers. Researchers found that the intent-to-treat group improved cognitive performance scores by 0.26 (95% CI, -0.89 to 0.54) compared to the 1.04 point (95% CI, 0.32 to 1.82) deterioration noted for those in the control group on the Alzheimer Disease Assessment Scale (0-70 points). Moreover, at 18- months follow-up participants from the intervention group improved 0.73 points compared to 0.04 improvements in the control group (CI 95%).

With little intervention research to examine the relationship between PA and cognitive health there is a considerable need for refining correlation methodologies appropriate for contributing to future research in hopes of identifying the causal effects of PA. Fortunately, several methods for assessing performance markers for both PA and cognitive health have been established (LaPorte et al., 1985; Etnier & Chang, 2009). \

In short, there is a need for the continued understanding of the association between PA and cognitive function in older adults. Advancements in PA monitoring tools, in concert with improvements in cognitive function testing, now provide adequate means for identifying PA’s relationship on cognitive health in older adults (Copeland & Esliger, 2009; Davis & Fox, 2007;

Gemmill, 2011; Harris, 2009; Santos-Lozanos et al., 2013). In this way, identifying strong correlation between the two variables with validated measures may improve the continued pursuit of causal relationships.

Purpose of the Study. The primary purpose of this study was to examine the relationship between PA and cognitive function test outcomes in older adults. A secondary objective was to determine if a significant difference between ACSM PA guidelines and cognitive performance exists within this cohort. Thus the results of this study may help further establish the linkage between PA and cognitive function and provide a dose – response counsel for future research and practice.

Hypothesis. It has been hypothesized that more PA older adults would demonstrate more optimal cognitive task performance than their less PA peers. Specifically, older adults meeting or exceeding the ACSM's current activity guidelines for older adults would experience less interference and score higher on Stroop Color and Word Test as well as complete TMT quicker when compared to less active peers.

Delimitations. The participant pool was restricted to older adults, free of diagnosed cognitive disorders, and between 65 and 99 years of age. Exclusion criteria consisted of individuals physically unable to walk without limitation, diagnosed with cognitive dysfunction, psychological disorders, color-blindness, or those taking psychotropic medications (anti-psychotics, anti-depressants, anti-obsessive agents, anti-anxiety agents).

Significance of the Study. Older adults are the most physically inactive group of any cohort (Davis & Fox, 2007; Harris, 2009) and adoption of PA is the most effective means of decreasing modifiable risk factors for dementia in this population (Brown et al., 2005; Nelson et al, 2007; Paffenbarger et al., 1994; Tanasescu et al., 1994). More research using validated PA and cognition methods is necessary to determine if PA has a dose-response influence as proposed by emerging research (Colcombe & Kramer, 2006; Etnier & Chang, 2009).

Increases in both dementia prevalence and incidence in coming years advocate an urgent need for considering PA as a primary and secondary prevention option. Simple assessments using updated techniques and technology may provide opportunity for both testing the role of PA for improving cognitive health and preventing cognitive decline in older adults. Furthermore, by more clearly identifying the correlation between PA and cognitive well-being dose-response counsel may be possible.

Limitations. Major limitations to the present study include its relatively small sample size (N=35) and unequal distribution of physically active to physically inactive participants (n=24, n=7) which may affect the generalizability of these findings. Cross-sectional designs only provide a snap-shot of the population making identification of causal relationships inaccessible. A further limitation to the present study included the lack of extant research regarding older adults and PA with specific regard to accelerometry measurement methods. The study was also limited by the availability of cognitive performance tasks due to funding limitations. Finally, visual acuity was a factor for several participants when trying to perform written and verbal cognitive tasks. Inability to clearly read smaller print and identify colors may have influenced the results of some of the participants herein.

Definition of Terms

Accelerometer – An instrument that assesses the frequency, duration, and intensity of physical activity.

Cognitive Function – Mental tasking that requires comprehension and learning. Specific examples include planning, strategizing, recalling (working memory), and response to stimuli.

Cognitive decline – deficiency in cognitive function uncharacteristic of changes associated with normal aging but not sufficient enough to inhibit activities of daily living (ADL)

Dementia – A syndrome, usually of chronic or progressive nature, caused by a variety of brain illnesses that affect memory, thinking, behavior and ability to perform ADL

Free – living physical activity – Necessary activities of daily life requiring energy expenditure above rest.

Physical activity – (PA) Any bodily movement produced by the contraction of skeletal muscles that substantially increases energy expenditure above rest.

Physical inactivity – (PIA) A behavioral state of not achieving, on a regular basis, minimal common standards of physical activity.

Exercise – a subset of PA that is planned, repetitive and purposed to improving or maintaining physical fitness.

Physical fitness – health and skill related traits (body composition, agility, muscular endurance, muscular strength and cardiorespiratory endurance).

Dose –response counsel – advice for behavioral conduct based upon an observable response as it relates to a specified amount of exposure to treatment.

Chapter 2: Review of Literature

Executive and Cognitive Functions Defined. The use of executive function terminology within physical activity literature has become complicated due to an inconsistency of definitions (Etnier & Chang 2009). The reason for this may rest in the density of the term. Executive function, commonly referred to as *controlled cognition, executive control* and *frontal lobe tasks*, is an umbrella term frequently used to address functions of “higher-learning.” These functions were first described by Kramer and colleagues (1994) as behaviors of planning, task coordination, initiation, inhibition and the processing of verbal information. Over time, subcomponents were adjusted to describe processes of planning, scheduling, inhibition, and working memory (Colcombe & Kramer 2003). These specific components of executive function are known individually as cognitive functions.

Assessment of Cognitive Functions. Cognitive functions, like physical aptitudes, are performance based. Assessments are useful by both researchers and clinicians to place meaningful understanding on an individual’s cognitive function. Likewise, obtaining tangible evidence of cognitive function allows researchers and clinicians to better define and describe cognitive processes. Like physical evaluations, both subjective and objective measurements tools are valuable in gathering such evidence. Rabin, Barr and Burton (2005) performed a comprehensive assessment of objective measurement tools and identified 29 tests that measure executive function. Of these, Wisconsin Card Sorting Test, the Stroop Test and TMT are frequently reported in PA literature (see Etnier & Chang, 2009; Salthouse, 2005). Relationships between these three tests are positive, yet weak in strength indicating their worth for measuring unique cognitive functions (Gilbert & Burgess, 2008).

An instrument capable of measuring all aspects of executive function does not exist, thereby supporting the multi-layered nature of the cognitive performance construct (Salthouse, 2005). This presents a problem for researchers trying to use and interpret measures of executive function. For this reason, multiple instruments are necessary to define and analyze various cognitive functions. To that end, Miyake and team (2002) proposed using multiple batteries to assess the broad construct and more accurately define executive function. Additionally, for study results to be interpreted and applied throughout physical activity and neuropsychology realms, validated assessment tools need to be used (Salthouse, 2005).

Trail Making Test. TMT has been widely used as a cognitive assessment and rehabilitation tracking tool for individuals age 11 – 74 (Gray, 2006). The test is regarded as a valuable tool evaluating executive function (Arbuthnott & Frank, 2000). Parts A (TMTa) and B (TMTb) were developed in 1938 as a means of measuring attention (Partington & Leiter, 1949). Part A measures attention and task processing, Part B focuses on planning and the ability to switch between mental processes.

As such, TMTa requires participants to order randomized numbers in ascending order as quickly as possible while TMTb requires them to order numbers and letters correspondingly in an ascending and alternating order. Both tasks are timed for completion. Through this assessment, detection of deficits in frontal lobe function, psychomotor speed, visual acuity, attention and mental-shifting can be identified and measured (Bastug et al., 2013; Gray, 2006). Executive function is tested by requiring the separation of task perception and response. This is most evident through TMTb where two distinct yet similar tasks must be managed.

Scoring of the TMT is based on raw task completion time and standardized T-scores. Also, differences in time of completion between TMTb and TMTa ($TMTb - TMTa$) are computed in order to identify potential cognitive dysfunction where lower difference scores indicate better cognitive performances. The test has been adapted over the past half-century into various forms, however; the traditional Part A and B task is still used as an acceptable psychological assessment and scoring tactics have remained consistent (Etnier & Chang, 2009). Normative tables for the original version of the test are thought to be representative of current U.S. population although little evidence substantiates this claim (Gray, 2006). In support of this claim Salthouse and colleagues (2005) for instance found no age or population outcome effects when administering the test to two randomized populations N =328 and N = 7,000, respectively.

Stroop Color and Word Task. Stroop task is a cognitive performance task used to test inhibition (Miyake, 2006). Inhibition, also known as interference, is one's ability to sort and selectively react to conflicting information (MacLeod 1991). This instrument, developed in 1935 by John Ridley Stroop has become a widely used valid measure of executive function (Salthouse, 2005).

Stroop task requires individuals to read a series of words (W), colors (C) and color-words (CW) from an 8 ½ x 11" card within a preset time of forty-five seconds. Stroop (1935) theorized that the ability to read these items would decrease with each progressing test series based upon earlier observations of word and color recognition tasks (by Cattell in 1886 reported by Golden & Freshwater (2002)). The CW portion of the test helps determine interference while W and C series serve as controls. Stroop's original hypothesis suggested the average person would read approximately half as many words in the allotted time between the three progressive tasks. CW item task response scores are directly related to the individual's ability to inhibit the word reading response. Those able to inhibit the word naming response yield a higher than predicted score indicating normal cognitive performance for the inhibition task.

Methods for scoring Stroop task vary (Golden & Freshwater, 2002; Jensen & Rowher, 1966). Two popular methods include raw time to complete 100 items and tallying number of items completed in a set time period (traditionally 45 seconds). Laboratory testing demonstrate no significant difference between the two scoring types (Golden & Freshwater, 2002). A set time limit offers advantages of a definite time, ease of use for both group and individual testing, and preventing frustration often experience in the 100 item test (Golden and Freshwater, 2002). Traditional scoring developed by Stroop (1935) uses the raw score timeline method. From these scores interference is determine by subtracting CW actual from CW predicted scores. Predicted CW scores are then calculated by multiplying word and color scores and dividing this value from the sum or word and color scores, W and C control scores are then compared for analysis (Golden & Freshwater, 2002). This is the most widely accepted method despite more complex proposals (MacLeod, 1991).

In regards to inter-individual differences, women were shown to perform better on color naming tasks (Golden, 2002; MacLeod, 1991; Stroop, 1935). Initially, Stroop (1935) indicated that women outperform men on W and C naming tasks. Peretti (1971) also reported significant difference between men (n =50) and women (n=50) on the CW task with raw scores of 48.2 and 55.1 items read, respectively. Follow up research in a group setting by Golden (1974) between men (N =102) and women (N =117) also found significant difference on raw scores ($\underline{t}$ = 1.33, $\underline{df}$ = 217). However, despite the slight advantage of women for the CW task, when the interference score is used the advantage is removed indicating no significant lead for women in clinical or experimental studies (Golden & Freshwater, 2002). As a result, for the purpose of analysis, there is no rationale for separating male and female respondents.

Stroop task reliability is consistent between all forms of the task (Golden & Freshwater, 2002). Test-retest experiments of periods between 1 minute and 10 days yield reliability > 0.70 (Jensen, 1965; Golden, 1975). Reliabilities of raw CW scores are also > 0.70 and little difference between correlations have been observed (MacLeod, 1991). Therefore Stroop remains a psychometrically sound tool to use in experimental research.

Cognitive Function and Disease. Dementia is a progressive condition characterized by declining cognitive function outside of what is considered normal with aging. Of the cognitive functions often affected, memory, thinking, comprehension, learning, and judgment are most noticeable in early stages of the disease (Wortmann, 2012). Alzheimer's disease is the most common type of dementia contributing to over half of all cases (Wortmann, 2012). The difficulties in identifying the disease come from the inter-individual variability if its symptoms, (Batsch & Mittleman, 2009). Stages are frequently used to determine the severity of conditions and use: early stage (first year or two), middle stage (second to fourth years) and late stage (fifth year and beyond).

Two to ten percent of all dementia cases begin in individuals younger than 65 years of age with prevalence doubling every five years beyond that age (Wortmann, 2012). Global aging estimates indicate the world population of individuals over the age of 60 will be two billion by the year 2050 translating into 115.4 million diagnosed cases by 2050 (Batsch & Mittleman, 2009). Dementia is the leading cause of disability and dependency in individuals over the age of 65 (Wortmann, 2012). Unsurprisingly, US$ 604 billion were spent in 2010 for formal and informal care options for these patients speaking to the clear health care cost burden associated with cognitive decline.

No proven treatment or prevention interventions exist for dementia (Wortmann, 2012). Studies of dementia incidence indicate smoking, diabetes, midlife hypertension, and elevated cholesterol to be strongly associated with the onset of dementia later in life (Kivepelo et al., 2001; Ott et al., 1999; Skoog et al., 1996; Whitmer et al., 2005) Furthermore, risk of incidence increases substantially depending on if exposure to these variables occurs during mid-life or just before dementia onset (Luchsinger, 2005). However, these studies only indicate potential improvements of the rate of incidence and do not highlight any direct treatment interventions.

Prevention and management of cardiovascular disease (CVD) risk factors are considered the most promising treatment plan for dementia and cognitive impairment (Political Declaration of the High-level Meeting of the General Assembly and the Prevention and Control on Non-communicable Diseases, 2012). Cohort studies suggest that PIA is a major risk factor for the onset of dementia because of its influence on multiple all-cause mortality risk factors (Barnes, Whitmer & Yaffe, 2007). Correspondingly, evidence supports a dose-response relationship between PA and CVD (Paffenbarger et al, 1999; Pate et al, 1995). The inverse relationship between physical activity and CVD further suggests an inverse response between PA and dementia prevalence. Lifestyle modification that includes the increase of PA has been suggested to eliminate 12.7% cases of dementia, and if all cardiovascular risk factors were eliminated, 50.7% of all cases would be eliminated worldwide (Wortmann, 2012). In fact, world-wide initiatives to make diabetes, hypertension, obesity, smoking cessation and better education public health concerns could serve the most benefit in positively affecting disease prevalence because of their inverse response relationship with PA (Physical Activity Guidelines Advisory Committee Report, 2008).

According to research examining all available epidemiological data on dementia prevalence in fourteen world regions, 24.3 million people aged 60 years and over were living with dementia in 2001 (Ferri et al, 2009). In accordance to these figures, incidence of 4.6 million new cases each year were proposed based on disease prevalence and mortality rates. Estimated median survival rates for individuals living with advanced stage dementia is 3.9 years (3.5-4.2 years) due to both direct and indirect causes (Fitzpatrick et al., 2005**)**. It is difficult to determine the direct cause of death for individuals with dementia as many have multiple comorbidities (Wortmann, 2012). Regardless, meta-analyses indicate mortality risk for those living with dementia as two and one half fold higher than those of the same age free of the disease **(**Dewey & Saz, 2001).

Newman and colleagues (2005) tested and observed men and women (N=3,602) for a period of 5.4 years. They indicated higher incidence of dementia among those persons with CVD prevalence noted during initial testing. Rates of dementia were 34.4 per 1,000 person-years for those with a history of CVD compared to 22.2 per 1,000 person-years for those free of CVD history. Similarly, a retrospective cohort study of men and women (N=8,845) indicated that smoking, hypertension, high cholesterol, and diabetes at midlife were associated with a 20 to 40% increase in risk of dementia (Whitmer et al., 2005). In addition, Whitmer's group noted that when compared to individuals free of cardiovascular disease risk factors, those with one or four risk factors were 1.27 and 2.37 times more likely to be diagnosed with dementia later in life. Taken together, findings from these studies suggest a strong correlation between CVD comorbidities and dementia.

Physical Activity. PA is a complex behavior characterized by bodily movement produced by contraction of skeletal muscle resulting in a marked increase in energy expenditure above rest (Caspersen, Powell & Christenson, 1985). Exercise is often considered to be synonymous with PA. Although PA and exercise host similar elements such as bodily movement of skeletal muscle to expend measurable energy expenditure, the two terms are distinct. The key difference is that exercise is planned, structured, repetitive and purposed PA meant to improve or maintain physical fitness (Caspersen, Powell & Christenson, 1985). Therefore, exercise is a subcategory of PA and although included in the PA umbrella, it is a specific element not a synonymous term. Likewise, physical fitness is a term sometimes confused with PA. Physical fitness is a set of attributes such as endurance, flexibility and strength that relate to an individual's ability to perform physical activity (Caspersen, Powell & Christenson, 1985). It is important to distinguish between these terms in order to clearly understand the unique influence these variables may have on health. Distinguishing activity terminology is essential in helping researchers investigate the individual impacts PA, exercise and fitness may each have on health and decreasing disease risk.

Energy expenditure is an objective variable which allows researchers to measure and make recommendations for PA. Increases in energy expenditure are most often reported as a unit of heat known as kilocalories (kcal). Since the definition of PA is relatively broad, subcategories are necessary to reliably measure energy expenditure and identify levels of intensity. Caspersen and colleagues (1985) identified two category systems for PA. The first divided PA into the periods of daily life during which activity occurs and can be represented by summing kcals from occupation and leisure to provide total daily PA energy expended. Leisure- time physical activity can be further categorized by finding the sum of occupational, condition, household and miscellaneous PA. The second categorizing system accounts for activities based on their intensity level and classifies these activities as light, moderate or vigorous intensity. This provides a simple categorical approach to PA assessments which can be beneficial for individuals who wish to monitor their own PA. By using these methods, energy expenditure can be measured and classified for participants in order to provide meaningful PA relationships with lifestyle.

There are several methods available to measure PA. LaPorte et al. (1985) identified calorimetry, job classification, questionnaires, physiological markers, behavioral observations, activity monitors and dietary estimates as the most effective subjective and objective PA measurement options. More recently, Strath and colleauges (2013) have identified the key domains of PA to be those of activity type, frequency of performance, duration of the activity and the intensity of performing the activity. Importantly, the group identifies multiple methods of assessing and measuring these domains. The report further highlights the advantages and disadvantages of subjective and objective methodologies. Of available measurement instruments, questionnaires and surveys have been the most popular due to their cost-effective and easy to administer nature. On the contrary, indirect calorimetry, physiological markers, direct observation and activity monitors have high associated cost and are more difficult to administer to large research groups. However, where these objective measures fail in regard to feasibility, they make up for in validity. The best approach seems to combine subjective and objective measures in order to fill gaps in instrument limitations (Shephard, 2003). The advantages and disadvantages of questionnaires and PA monitors will be discussed further as they serve as the principle measure of PA in the current study.

Questionnaires. The appeal of PA questionnaires are their relatively low cost and ease of administration to various ages. These instruments come in paper and electronic formats and can be administered individually or to large groups. Several instruments are available based on the population's age, size and the overall study purpose (Sallis & Saelens, 2000; Strath et al., 2013). Subjective instruments can be administered under direct supervision and instruction or used as self-report measures. Reports vary in their complexity. Some questionnaires may ask one question regarding an individual's activity while others may probe deeper into time, duration, frequency and type of activity (Pereira, et al., 1997).

Self-report PA questionnaires are subject to recall bias and an individual's ability to remember details over extended periods. It is has been established that individual's best recall events of extreme duration or vigorous activity and also report information that may appear more pleasing to the researcher (Sallis et al., 2000). Shephard (2003) noted that sensational impairments and cognitive disorders can introduce bias in research with older adults. These concerns have been source of inquiry for the validity and reliability of existing measures with older adults. Most popular instruments are however backed with psychometric evidence for sound use with older adults (Sallis & Saelens, 2000).

Of importance to the current study, the International Physical Activity Questionnaire (IPAQ) was developed as an universal activity instrument. The questionnaire was shown to produce reliable scoring (Spearman's ρ 0.08) and validity held a median ρ of 0.30 comparable to other well accepted self-report measures (Craig et al., 2003). This suggests that the IPAQ is a reasonable tool for assessing PA and PIA. However, with specific regard to the use of this instrument in older adults Heesch and colleagues (2010) identified difficulties for these individuals. Namely older adults have been shown to have difficulty in reporting PA once per category, quantifying normal tasks as moderate to vigorous, and problems quantifying time sitting. Therefore, the IPAQ requires special consideration for administration and explanation for adults ≥ 65 years. Other PA assessment instruments are available for older adults but are less feasible for administration due to cost and length (Craig et al., 2003).

Physical Activity Monitors. PA monitors provide objective measures of an individual's daily activity. Heart rate monitors, accelerometers and pedometers can be used to estimate energy expenditure. These tools are reasonably priced compared to other objective methods and capable of tracking patterns of PA over long time periods. Major benefits to these devices are their accurate detection of changes in PA levels (Tudor-Locke & Myers, 2001), relative ease of use, unobtrusive size, ability to store large amounts of data and accompanying software analysis packages.

Shortcomings of pedometers and accelerometers rest mainly on their ability to primarily detect ambulatory movements (Montoye, et al., 1996). Bicycling, resistance training, swimming and other non-ambulatory modes of PA are often not captured completely and can be elusive when analyzed. For this reason, activity logs often accompany these devices in order to aid researchers in the interpretation of raw PA data. Furthermore, gait abnormalities can make activity counts difficult to measure. Namely, soft walking patterns and slow movements often associated with older populations can be difficult to detect. An additional limitation of these devices are the labor intensive data analyses necessary to accurately determine PA patterns, as well as technical skills to download and interpret large data sets.

Accelerometers. Accelerometers measure movements based on acceleration and deceleration. Because of this, they can be used to determine energy expenditure as activities captured have a proportional relationship with muscular forces. Accelerometers are versatile tools because they can be placed on the wrist, waist or ankle and used to capture different types of movement. Also, accelerometers store data based on time and frequency which allow researchers to determine the length, the frequency, and the intensity of the physical activities individuals perform. Newer accelerometer models detect movement in vertical, horizontal and medio-lateral planes (tri-axial) allowing a capture of activity throughout a variety of movements.

Accelerometers are limited in detecting upper body movements when worn on the hip and ankle and likewise can misrepresent ambulatory activities when worn on the wrist. The most accurate means of PA assessment comes with wearing multiple devices, although this is less practical due to increased cost, data interpretation and burden to the participant (Bassett et al., 2000).Validity studies which correlate free-living PA with energy expenditure measured through laboratory controls have been shown to differ significantly (Crouter et al., 2003). This is likely because treadmill activities are regulated with determined walking speed increments and free living PA is unstructured and much less predictable. Another challenge to assessments outside of controlled laboratories is determining how many days the device should be worn in order to provide valid and reliable data counts. Multiple validation studies suggest 4 days (3 weekdays, 1 weekend day) of greater than 10 hours of wear-time per day to be acceptable for accelerometers and pedometers (Trost et al, 2000 as cited by Gemmill et al., 2011; Tudor-Locke et al., 2004) where others have chosen arbitrary criteria (Boucard et al.,2012). Consensus and practice agree on the former in order to capture a full week of PA data. In this way it is postulated that a week of data is synonymous with any given week for the participant and is therefore a sound representation of normal PA patterns (Tudor-Locke., 2004).

Advances in accelerometry have led to the development of several new devices over the last decade. Additions of pedometer step count capabilities in these devices have eliminated the need for separate step count devices and assessments. The most notable advancement in this technology is the shift from uniaxial (GT1M, ActiGraph) to tri-axial devices (GT3x, ActiGraph) which allows monitoring of activities in three planes as opposed to only the vertical axis. Several studies have investigated the reliability and validity of these monitors with both an inter-monitor and between monitor approach (Santos-Lozano, 2012; Sasaki, 2011). Santos-Lozano and colleagues (2012) placed eight GT3x (ActiGraph) accelerometers on one individual and assessed six walking conditions, as well as a repeated sit to stand task. Correlation coefficients for all three axes suggested strong reliability (≥ 0.925) between devices. This indicates the value of accelerometers for research and reliable assessment of PA patterns.

Multiple studies have compared the reliability of the GT3x (ActiGraph) with a GT1M uniaxial model (one generation older). Their findings showed little agreeability between the GT3x and GT1M devices. GT1M activity counts reported increased activity counts for all activity assessments compared to the GT3x (Kaminsky & Ozemek, 2012; Sasaki & Freedson, 2011). The advancement of accelerometer devices from the traditional uniaxial units to the more advanced tri-axial devices has impeded the ability of researchers to interpret research between device generations, across the lifespan, and between population groups (Matthews, 2005). These limitations point to future research directives that will develop prediction equations for a wide range of PA intensities, activity count thresholds and comprehensive objective assessments of the most commonly encountered physical activities (Copeland & Esliger, 2009; Matthews, 2005).

Researchers have further noted difficulty in determining PA counts and energy expenditure between population groups using identical devices (Copeland & Esliger, 2009; Matthews, 2005; Santos-Lozanos et al., 2013). Santos-Lozanos' and colleagues (2013) concluded that the GT3x (ActiGraph) device was a good predictor of PA patterns and energy expenditure for young adults and adults, but not for older adults. Most PA and energy expenditure measures have been established for younger populations (Dubbert et al., 2004; Strath et al. (2012) resulting in a gap of objective PA research among older adults. Older adults are often limited in mobility and do not participate in MVPA (Gemmill, 2011; Harris, 2009) thus adding to the limited data available for energy expenditure and PA assessments. In addition, aging effects and cognitive health can present significant challenges to accelerometer protocol adherence by decreasing activity and compliance, respectively (Gemmill, 2011).

In order to overcome limitations of sensitive populations, Ozemek et al (2013) proposed the use of relative PA counts based on linear regressions between activity counts and heart rate reserve (HRR). To accomplish this, individuals were asked to walk on a treadmill while heart rate was monitored. Linear regression between counts/minute at a given walking speed were plotted against heart rate for the same point in time. This way inter-individual differences are eliminated and the individuals' activity counts/minute registered by the device are interpreted relative to their own movement and activity intensities become their own. Furthermore, physical limitations that hinder absolute thresholds for PA categories are eliminated. However, disadvantages to this method are the reliance of linear heart rate responses which can be blunted by medication intake and health status of older adults as well as the need for a true maximal heart assessed through functional stress testing.

Activity Counts. Few attempts have been made to establish valid activity cut points for older adults. In a study of 38 older adults (M= 69.7 years) Copeland and Esliger (2009) suggested 1,041 counts/minute be the threshold for MVPA. However, this study was conducted with early generation uniaxial monitors which have been shown to over-estimate activity counts hence the difficulty to transpose its guidelines to contemporary devices (Sasaki & Freedson, 2011). A need for continued calibration studies is necessary as large population-based studies (see National Health and Nutritional Examination Survey as reported by Troiano and colleagues (2008)) are beginning to collect PA data using accelerometers. Recently, Santos-Lozanos and team (2013) established cut points for older adults (age 65 – 80) with GT3x tri-axial generation accelerometers. These activity cut points were determined by comparison to energy expenditure measured by indirect calorimetry. Based on this data, Santo-Lozanos and team concluded that activity greater than 2,751 counts/minute were equivalent to MVPA.

Impacts on Health. Even with well documented health benefits from PA, older adults are the least active cohort of any group (Centers for Disease Control and Prevention; CDC, 2003; Davis & Fox, 2007; Federal Interagency Forum on Aging-Related Statistics, 2004; Harris, 2009). Current PA recommendations by the ACSM and American Heart Association suggest older adults participate in MVPA on preferably most, but at least 3, days each week for a duration of 30 – 60 minutes for moderate and 20 – 60 minutes for vigorous intensities (Haskell, 2007; Nelson, 2007). A survey of 74,960 older adults assessing PA and PIA status showed that a total of 43.4, 39.1 and 17.5% disability free older adults were active at recommended levels, insufficiently active and inactive respectively (Brown et al., 2005; CDC, 2005) affirming the high incidence of PIA among this age group. Likewise, in a study of older men and women (N=560) which assessed PA patterns by use of pedometer and accelerometer only 2.5% of participants achieved the recommended 150 minutes of weekly MVPA and 62% achieved no activity for minimally recommended ten minute bouts (Harris, 2009). Older adults often associate occupational and mandatory tasks as a viable substitution for PA. Research however, has shown that work-related PA is insufficient and that leisure-time PA is necessary for health benefits (Ruvio et al, 2007). Considering the importance of PA on health, this is disconcerting evidence.

Several reports have confirmed the direct dose-response relationship of PA on health and decreased all-cause mortality risk factors (Ferrucci et al., 1999; Lee & Skerrett, 2001; Nelson et al., 2007; Paffenbarger et al., 1994; Pate, Pratt & Blair et al., 1995). Specifically, large epidemiological studies have identified a strong inverse dose – response relationship between PA and CVD (Lee et al., 2001; Manson et al., 2002; Tanasescu et al., 1994-2000, Yu et al., 2003).

Perhaps one of the most compelling arguments for the benefits of PA come from two pioneering studies which looked at the relationship between PA and all-cause mortality. Paffenbarger and colleagues (1993) conducted a long-term study looking at the influence of mortality of over 14,000 male Harvard College alumni aged 45 – 84 years. They concluded that those adopting a physically active lifestyle, characterized by an energy expenditure of > 1,500 kcals per week, were at a significantly lower risk of mortality (0.72, 95% CI 0.64-0.82) compared to their less active peers. Men who began participating in moderate to vigorous recreational sport were also found to be at a lower relative risk (0.73, 95% CI 0.54-0.95) when compared to men who did not participate in equivalent leisure time activity (1.00). In addition, this team noted a substantial increased risk of mortality in smokers (0.82 95% CI 0.57-1.23) versus non-smokers (0.49 95% CI0.38-0.63) as well as between normotensive (0.54 95% CI 0.40-0.73) and long-term hypertensive persons (1.00).

Second, the Aerobics Center Longitudinal Study prospectively observed 10,000 men and 3,000 women over 8 years. Initial and follow up medical examinations and maximal exertion treadmill tests confirmed an inverse relationship between cardiorespiratory fitness and all-cause mortality. Notably, least fit men and women were 3.44 (95% CI: 2.05-5.77) and 4.65 (95% CI

2.22-9.75) times more likely to die of any cause than most fit men and women (Blair et al., 1989). A follow up to this study suggested that for every minute of increase in time to exhaustion on a maximal exertion test, risk of CVD would decrease 8% (Blair et al., 1995), thereby emphasizing physical activity's positive influence on health. The significance of these reports in regard to dementia is evident in the strong relationship observed between CVD prevalence and dementia incidence (Newman et al., 2005; Whitmer et al, 2005).

Physical Activity and Cognitive Function. While the benefits of PA on CVD and numerous other health related variables are well established, the impact of PA on cognitive well-being is less clear (Etnier & Chang, 2009). Developments in objective PA measurements over the last 30 years may be a factor in study discrepancies (Matthews, 2005). In addition, varying use of cognitive function terminology has made many study results difficult to discern (Etnier & Chang, 2009). To date, a weak support base exists in the literature due to inconsistencies of research practices. Shortcomings in PA and cognitive well-being assessments can be attributed to gaps in knowledge and methodological differences. Data from self-report studies, undistinguishable effects of PA type (aerobic or anaerobic), failure to assess duration, frequency and intensity of activity and the inability to identify early signs of dementia have all convoluted the effects of PA on cognitive function (Kramer, 2006). Such confounds require additional well executed random control trials to accurately discern the effects of PA on executive functions.

Multiple meta-analysis studies have identified protective effects of exercise and PA on cognitive health (Etnier, 1997; Colcombe & Kramer, 2003; Kramer et al., 2006; Sofi, 2010). Yaffe and colleagues (2001) in a prospective study of 5,925 women over the age of 65 noted that those with higher baseline PA levels were less likely to develop cognitive decline at the 6 – 8 year follow up. Around the same time, a study exploring PA and cognitive decline risk noted that PA was associated with a lower risk of dementia. In fact, the study concluded that higher PA levels equaled diminished risk of dementia of any type (0.63, 95% CI 0.4 – 0.98) of the 4,615 older men and women assessed after 5 years (Laurin, 2001). Similarly, Eggermont and colleagues (2009) noted in a study of 544 men and women (M= 78 years) that individuals reporting higher PA performed better on cognitive performance tasks.

The aforementioned studies included only self-report PA measures due to large sample sizes. This said, studies using objectives measures have shown similar results. Boucard and colleagues (2012) examined difference of sedentary and active older adults as determined by accelerometry, cardiovascular fitness (determined by maximal exertion testing) and multiple other measures. Conclusions from the study indicate that increased PA and fitness had a positive effect on cognitive function. Zvinka (2013) and team used Magnetic Resonance Imaging to map brain activity patterns during language tasks. Consistent with the previous findings, active older adults showed marked improved performance on the cognitive task suggesting regular PA as a means of inhibiting cognitive decline.

The benefits of PA on cognitive health are further recognized as the literature continues to grow. Objective measuring tools are giving insight into the poor PA adherence of older adults and furthermore providing opportunity to study the detrimental effects that sedentary lifestyles promote. Similarly, patterns of PA in older adults have also become better established. Davis and Fox (2007) assessed PA patterns between old and young adults where older adults were found to be 37% less active daily and were not meeting recommendations for MVPA. This presents a substantial problem as low PA is inadequate to produce health benefits necessary to combat chronic illness (Haskell, 2007; Nelson, 2007; Paffenbarger, 1994).

Numerous meta-analysis and prospective studies have indicated the positive effects of increased PA on cognitive health. However, randomized control trials (RCTs) are lacking (Barnes, Whitmer & Yaffe, 2007; Etnier & Chang 2009). RCTs are the gold standard for determining casual effects. Barnes and colleagues (2007) in a review of short-term PA interventions noted that on average, PA groups improved upon cognitive function performance compared to less active controls. Regardless of this evidence suggesting acute improvements in cognitive performance no studies have examined the causal effects of long-term PA on cognitive decline and dementia (Barnes et al., 2007). RCTs are now necessary in order to back the evidence of longitudinal and prospective research.

To date, one RCT has attempted to assess the causal relationship between PA and cognitive function by use of activity intervention. Lautenschlager and colleagues, (2008) tested cognitive performance of 138 older adults (> 50 years) before and after a 24-week PA intervention. The researchers found that the intent to treat group improved by 0.26 points where the control group cognitive performance deteriorated by 1.04 at the end of the intervention. Moreover, at the 18-month follow up period those in the intervention group improved 0.73 points on the cognitive task compared to 0.04 point improvement of those in the control group. More studies like this are warranted in order to better understand the causal relationship PA has on cognitive function.

Improvements with objective PA measurements tools and cognitive performance instruments provide an opportunity to accurately measure and compare these variables. Eliminating exclusive use of subjective PA questionnaires and instead using them to complement objective assessments can provide more reliable answers to inquiries regarding physical activity’s impact on cognitive function and dementia prevalence. Introducing this technique offers a unique opportunity to provide more reliable activity time and intensity reports for older adults. No single technique has been established when comparing subjective recall questionnaires and surveys to raw activity counts. The most practical approach is to use these logs to identify activities and durations which may not be accurately captured by the accelerometer. Identifying these activities allows researchers to determine energy expenditure by comparing reports to the ACSM's PA compendium which lists energy expenditure values for a myriad of common physical activities. From this comparison researchers can then provide more reliable activity reports.

Controversy still exists regarding the degree of influence PA has on cognitive decline (Etnier & Chang, 2009; Sofi, 2010). In order to extend the existing literature consistent measurement tools and methods need be implemented. To that end, interdisciplinary research at the conjunction of PA and cognitive function expertise can prove especially beneficial.

A review of the extant literature points to the need of using multiple cognitive performance instruments and using objective PA monitors in concert with subjective instruments to provide a better understanding of the relationship that exists between PA and cognitive function (Boucard et al., 2012; Kramer, 2006). The primary purpose of the current study was to examine the relationship between PA and cognitive function test outcomes in older adults. Furthermore, it was the intent of this study to add to the current literature by using objective PA assessments in order to provide a more accurate analysis of PA. The secondary objective was to explore difference between PA categories proposed by the ACSM and cognitive function exists within the older adult cohort.

Chapter 3: Methodology

Sampling. Ball State University's Institutional Review Board approved this study. Twenty-one male and 14 female participants over the age of 65 were recruited by word of mouth, flyers and campus wide e-mail to complete the study. Participants were recruited from Ball State University's current and alumnus staff as well as from the Muncie, IN. region. Two visits to the Human Performance Laboratory were required for testing. The mean age of the group was 70.6 ± 4.6 years. Prior to the first visit participants were screened by researchers for psychotropic drug use, diagnosed cognitive disorders, color blindness and mobility issues that would prevent participation in the study. A Health History Questionnaire and Information Letter were also sent to the participant to fill out and bring with them prior to the first visit. Of the 35 eligible study participants, N=32 completed all tests and were included for analysis. Three particpants' data were eliminated from accelerometer analysis due to non-compliance.

Protocol Visit One. Participants read and signed the informed consent. The researcher explained all test procedures, data collection methods and the purpose of the study. Participants were encouraged to ask question at any time during testing. A health history questionnaire was administered in order to ensure that all inclusion criteria were met. Age, education level, medications, and PA habits were assessed from this questionnaire. Resting heart rate and blood pressure were taken as follows in accordance with *The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure* (JNC7). Participants rested in the seated position for a period of 5 minutes before resting heart rate and blood pressure were measured. Heart rate was taken by palpating the radial artery and counting total pulse beats for a period of one minute. A second heart rate was measured in the same way after 30 seconds to improve validity. Resting blood pressure was taken on the left arm, pending anatomical contraindication, with an aneroid sphygmomanometer (Tycos 509 Welch Allyn Inc., Skaneateles Falls, NY). Two blood pressure measures were taken 30 seconds apart by a trained technician. Differing systolic values greater than six millimeter of mercury (mmHg) or diastolic readings greater than four mmHg in difference required a third reading. In the case of three measurements, two measures within six systolic or four diastolic mm Hg were averaged. Otherwise, the lowest of the two measures was used.

Height and weight were taken using a standard wall stadiometer (Seca 216 Chino, CA) and digital floor scale (Health – O – Meter Professional 349KLX Sunbeam Products, Inc., McCook, IL.) and rounded to the nearest quarter inch and pound, respectively. The researcher instructed participants to remove shoes, heavy items and jewelry before measurements. Body mass index (BMI) was calculated by multiplying weight in kilograms with squared meters. Waist-to-hip circumference ratio was determined in accordance to ACSM guidelines (2014) using a tape measure with spring-loaded handle. The narrowest point between the umbilicus and xiphoid process was divided by the widest point below the umbilicus and above the iliac crest to provide the ratio. Measurement were taken in centimeters.

The researcher, in a private room free of distraction, administered both cognitive tasks individually. TMT is a two-part instrument used for the assessment of cognitive function defect. Both parts of TMT include 25 circles randomly distributed over a white sheet of paper. In Part A (TMTa), circles are numbered one thru twenty-five and the participant was instructed to connect the numbers in order without lifting their pencil from the page as quickly as possible. In Part B (TMTb), circles were labeled with numbers one through twelve and letters A to L. The participant was instructed to connect a continuous line between each number and letter combination in ascending and alternating order between the number line and alphabet sequence as quickly as possible. In case of errors, researchers pointed out the mistake and the participant immediately made the correction. TMT and Stroop Task were given to participants in a private room free of distraction. Each task was timed to the nearest tenth of one second. Researchers recorded total time to perform TMTa and TMTb separately. TMTa and TMTb were administered separately with clear verbal instruction given by the researcher to the participant before each task. The test was placed upside down on a flat surface prior to being administered. Participants were given an opportunity to ask questions regarding the task prior to task onset. Participants were not able to turn the test over until instructed to do so. Test timing began when the pencil was placed on the first item and ceased when the final item was marked.

Stroop test cards were given to the participant in the form of a test booklet. Participants were not permitted to open or begin the test until the researcher gave instruction to do so. Participants were not allowed to rotate the cards more than 45˚ in either direction during the task or lift the card from the table. Participants were not allowed to cover any portion of the test item they were reading and the test booklet was required to lay flat on a flat surface during assessment. These criteria were given in order to prevent participants from manipulating the test to improve outcomes. Turning the card or covering a portion of the word is thought to focus the reader’s attention on the color and thus eliminate the word component of the task (Golden & Freshwater, 2002).

Each of the three cards were issued separately as individual tasks. Card I consisted of 100 words (red, green and blue) printed in black ink on a white sheet and arranged randomly with no words being repeated consecutively within a column. Card II consisted of 100 colors items (written XXXX) printed in red, green, or blue ink on a white sheet. Colors are randomly distributed throughout the page and no color is repeated within a column or printed to match the corresponding colors of card I. Card III also involved 100 colored-words on a white sheet. The order of the words from card I are printed in order of the colors of card II. For example, the first word on card I is printed in the first color of card II in order to produce the color-word on card III. In this way, no word matches its printed color. Participants were given 45 seconds to read aloud as many items as possible. Timing began when the first item was read aloud and stopped when the alarm from the alarm clock sounded. The final word read was marked by the researcher. The following script was read to each participant prior to beginning the first task:

> ”*This is a test of how fast you can read the words on this page. After I say begin, you are to read down the columns starting with the first one until you complete it then continue without stopping down the remaining columns in order. If you finish all the columns before I say "Stop", then return to the first column and begin again. Remember, do not stop reading until I say "Stop" and read out loud as quickly as you can. If you make a mistake, I will say "no" to you. Correct your error and continue without stopping. Are there any questions? Ready? Then begin. (After 45 seconds) Stop. Circle the item you are on. If you finished the entire page and began again, put a one by the circle."*

The instructions were identical for all three cards with the exception that the participants were asked to name the word, color and color of the ink the words were printed in for cards I, II and III, respectively.

Accelerometry (ActiGraph Model GT3X tri-axial accelerometer; ActiGraph, Pensacola, Fl., USA) was used to assess free-living and leisure-time PA over a seven-day period. Participants were asked to wear the device over the right hip for a period of one week. The accelerometer was initialized for the participant using subject ID, gender, height, weight, date of birth (DOB) and race. Accelerometer sampling rates were standardized at 60Hz. The device measured acceleration and deceleration counts in the frontal, medio-lateral and vertical planes. Participants were asked to wear the device for 10 hours/day for seven days. These time criteria were used for data validation. The researcher, through verbal and written method gave instruction on how to wear the device. The researcher demonstrated how to wear the device over the right hip. Participants were asked to demonstrate how to attach the device to the researcher. The device was only to be removed during bathing, water activities and before going to bed each night. Accompanying the device was an activity log sheet.

This daily log requested participants to document time the device was not worn, duration and type of physical activities, exercise, and any atypical activities such as sustained sedentary or activity time each day. This log sheet was used by the researcher during final analysis to interpret activity count data. The log sheet was used for comparison to help ensure that objective activity counts matched subjective recall. In specific instances where activity modes were not captured through accelerometry, the log sheet minutes were used for final interpretation by adding minutes of such activities (swimming, cycling, rowing) to accelerometer PA minutes recorded by the device. The Compendium of Physical Activities was used to confirm workload intensity in order to ensure that activity minutes were MVPAACC+ to PA categories appropriately (Ainsworth, 2004). This technique was used only when duration and intensity information were provided by the participant. This method was applied for eleven participants. For six of these participants this information was obtained from their local fitness center's data log as reported by an exercise specialist. For all eleven participant's, intensity was determined by The Compendium of Physical Activities where ≤ three metabolic equivalents (METs) were considered light/sedentary PA and ≥ three METs were considered MVPA (Ainsworth, 2004).These activity minutes were then MVPAACC+ to accelerometer minutes and used for this report. The addition of MVPA and log sheet counts are termed $MVPA_{ACC+}$.

Visit Two. Participants returned the accelerometer to the Human Performance Laboratory after 7 days of wear time. The researcher validated compliance criteria using ActiGraph software. 6.8.0. If the criteria were not met, participants were asked to wear the device for an additional 7 days. Wear time validation criteria were met if the participant wore the device for ≥ 4 days (3 weekdays and 1 weekend day) for ≥ 10 hrs. /day. Subject data insufficient to meet wear-time validation following two assessment attempts were removed from analysis. Activity counts from the accelerometers were collected, interpreted and categorized as time spent in sedentary, light PA or MVPA based on activity thresholds. Santos-Lozano's cut points for older adults were used for analysis (2013). In addition, device software provided energy expenditure from activity counts and participant anthropometric data. Total step counts were also attained through the devices pedometer function.

Analysis. Accelerometer raw data counts were analyzed using ActiLife Software 6.8.0. Wear time compliance and mean counts/day were validated through the software. Based upon activity counts established by Satnos-Lozanos (2013) participants were considered to be either PA or PIA. Subcategories of PA and PIA were further broken down into reporting of sedentary, light, moderate or vigorous PA. The ACSM (2014) suggests that all adults participate in ≥ 150 minutes of moderate activity or 60 minutes of vigorous PA each week to maintain and improve health and fitness adaptations. These criteria were used to determine PA classifications where those achieving ≥ 150 moderate or ≥ 60 minutes of vigorous activity were considered PA and those achieving less than these standards were categorized as PIA. All activity greater than 2,751 counts/minute were considered MVPA. Sedentary counts were categorized by periods of immobility greater than 30 minutes and an activity threshold < 99 counts/minute. Light PA consisted of counts greater than sedentary and less than MVPA.

TMT and Stroop task t-scores were used to determine cognitive function. TMT was scored by use of total time to perform the task. Participants were categorized by percentile for men and women there age based on normative data reported by Tombaugh (2004). Scores from Part A and Part B yielded a raw difference score. Percentile scores < 50% and raw difference scores reported in seconds > one standard deviation from the mean indicate possible cognitive impairment.

Stroop Task was scored, analyzed and interpreted as followed. Raw scores were reported as total items read in the 45 second time limit. These scores were assigned for C, W, and CW, respectively. Raw scores were then used to determine an individual's Residual score based on his/her education status and age. Residuals scores were then used to derive t-scores reported by Golden and Freshwater (2002) for each of the three parts of the task. Interpretation used t-score values. Common patterns of the Stroop scores also reported by Golden and Freshwater (2002) were used for indications of poor, normal, or exceptional cognitive performance. Specifically, common patterns for the CW scores were used to indicate possible cognitive interference. In addition, interference scores were created by subtracting predicted CW scores from raw CW scores. From this calculation an interference t – score was generated for reporting and cognitive indication.

Statistics. Correlation analysis was used to test the relationship between PA and cognitive function. Objective and subjective MVPA measures were compared to each cognitive performance task outcome (Stroop W, Stroop C, Stroop CW, TMTa and TMTb), as well as other PA variables. Pearson's product moment correlation and significance were reported for these comparisons. Independent t-tests were used to examine the relationship between physically active and physically inactive groups. Effect sizes were reported using Cohen's d test. Data analysis was performed using SPSS version 20 for Windows (SPSS Inc., Chicago, IL). Cohen's d effect sizes were calculated for all t-tests using online software (uccs.edu/~lbecker/). Significance was set at the $p < 0.05$ level for all statistical tests.

Chapter 4: Manuscript

Title: Physical Activity and Cognitive Function Outcomes in Older Adults

Abstract

Purpose: The purpose of this study was to examine the relationship between PA and cognitive function in older adults by use of multiple cognitive performance tasks and objective PA monitors (ActiGraph GT3x). Additionally, the current study sought to determine if older adults adhering to ACSM PA guidelines would exhibit significantly better cognitive function than their active peers. **Methods:** Thirty-five participants, 21 males and 14 females ($M = 70.6 \pm 4.6$ years), were included for analysis. Resting heart rate, blood pressure, health history and basic body composition variables were measured. Trail Making Task and Stroop Color and Word Test were used to assess cognitive function. PA was measured for a one week period by accelerometry (ActiGraph GT3x). **Results:** Weekly MVPA as measured by accelerometry ($MVPA_{ACC+}$) was found to correlate significantly with W ($r = .446$, $p = < .05$), C ($r = .389$, $p = < .05$) and CW ($r = .609$, $p = < .05$) performance outcomes. $MVPA_{ACC+}$ was also found to have a significant relationship with TMTb outcomes ($r = -.358$, $p < .05$). $MVPA_{ACC+}$ was shown to correlate with $MVPA_{IPAQ}$ ($p < .05$, $r = .521$) while Sedentary/light PA_{ACC} and Sedentary/light PA_{IPAQ} did not show a significant relationship ($r = .675$, $p = .08$). Total steps/week were strongly correlated to $MVPA_{ACC+}$ ($r = .752$, $p = < .05$) as well as Stroop CW scores ($r = .388$, $p < .05$). Energy expenditure also correlated with CW ($r = .656$, $p < .05$) and TMTb ($r = -.532$, $p < .05$). Women were shown to have a stronger relationship between $MVPA_{ACC+}$ and TMTb performance outcomes ($r = .732$, $p < .05$). Independent t-tests indicate that older adults participating in > 150 minutes of MVPA weekly perform better on Stroop W, C and CW ($p = .003$, $p = .001$, and $p = .015$, respectively) when compared to less active peers. **Conclusions:** Increased MVPA indicates

improved cognitive performance outcomes in older adults when compared to less active peers.

Keywords: Physical Activity, Cognitive Function, Accelerometer, Older Adult

Introduction

In 2010, the World Health Organization (WHO) estimated worldwide dementia incidence to be 35.6 million cases. Successive prevalence predictions suggest that by 2030, 65.7 million individuals will have the disease. With a globally aging population, the number of those effected by the disease will grow beyond 115 million by 2050. In line with these predictions it has been confirmed by the WHO that the care costs associated with dementia in 2010 were US$ 604 billion.

To date, no conclusive treatment or prevention interventions are available for those with the disease or at increased risk (WHO, 2012). Dementia incidence studies have indicated that smoking, diabetes, midlife hypertension, obesity and elevated cholesterol are strongly associated with dementia disease onset later in life (Kivepelto et al., 2001; Ott et al., 1999; Skoog et al., 1996; Whitmer et al., 2005). This evidence further suggests that the management of cardiovascular disease (CVD) risk factors remains the most promising treatment plan for dementia and cognitive decline Furthermore, cohort studies suggest that physical inactivity (PIA) is a major risk factor leading to the onset of dementia because of its robust influence on aforementioned mortality risk factors (Barnes, Whitmer & Yaffe, 2007). Paffenbarger and colleagues (1999) demonstrated an inverse relationship between physical activity (PA) and CVD indicating the value increased PA may have on cognitive function and dementia prevention.

The American College of Sports Medicine (ACSM) has acknowledged the beneficial influence of physical activity (PA) on health (Haskell et al., 2007). Consequently, evidence has been applied to provide dose-response recommendations of PA on several modifiable comorbidity risk factors. Current recommendations for older adults suggest 150 minutes or 70 minutes of moderate to vigorous PA (MVPA) respectively each week in order to produce benefits on health and fitness (Haskell et al., 2007; Nelson et al., 2007). Despite this evidence, older adults remain the most physically inactive cohort of any group. A study by Harris and colleagues (2009) showed that 2.5% of older adults are meeting ACSM recommendations while 62% achieve no MVPA in any given week.

Although the dose – response relationship between PA and all-cause mortality, cardiorespiratory disease, metabolic disease, weight management, musculoskeletal and function health is well established, the association between PA and cognitive health remains weak (Physical Activity Guidelines Advisory Committee Report, 2008). Conflicting approaches from PA specialists, exercise psychologists, and neuropsychologists examining potential effects of PA and cognition through varied approaches have left gaps in practice that prove difficult to fill (Barnes, Whitmer & Yaffe, 2007).

Longitudinal and meta – analysis studies identifying the role of PA on dementia prevalence and incidence are relatively new (Etnier & Chang, 2009; Kramer, 2006; Sofi, 2010). Due to the infancy of the extant research, primary prevention recommendations have not yet been established. Few studies have assessed PA and cognitive function by use of objectively measures of PA (i.e., accelerometers) and even fewer have compared these PA assessments to multiple cognitive performance task outcomes (Barnes et al., 2007; Boucard et al., 2012). To date, only one intervention study has empirically assessed PA and cognitive performance outcomes in older adults. This study, conducted by Lautenschlager and colleagues (2008) randomized older adults (N=138) into a group receiving a 24-week PA intervention and a control groups. Researchers found that the treatment group significantly improved cognitive performance scores compared to controls after a 24-week PA intervention. More studies are necessary to objectively assess the influence PA may have on cognitive function.

The primary purpose of this study was to examine the relationship between PA and cognitive function test outcomes in older adults. This objective was pursued by using multiple cognitive performance tasks and objective PA assessment instrumentation. A secondary objective was to determine if a difference between the ACSM PA recommendations and cognitive performance exists within this cohort. It was hypothesized that more physically active older adults would perform better on cognitive performance outcomes than their less active peers. As an exploratory hypothesis, it was supposed that those adhering to MVPA durations, as recommended by the ACSM, would have more optimal cognitive task performance outcomes than those not achieving current ACSM guidelines.

Methods

Subjects. A total of 35 older adults were recruited via e – mail, flyers and word of mouth from Muncie and the surrounding region. Prior to participation, subjects were screened for pre – existing cognitive disorders and prescribed psychotropic medication regimens which would exclude them from the study. Additionally, participants were informed of the purpose, procedures, risks and benefits of the study and were required to sign an informed consent. Inclusion criteria were males or females over the age of 65 years free of diagnosed psychological disorders and psychotropic medications. Volunteers unable to walk without assistance and those suffering from color-blindness were also excluded from the study. Three participants were excluded from accelerometry analysis because of missing PA data. Detailed descriptive characteristics of the sample group presented in Table 4-1.

Visit One Participants read and signed the informed consent. The researcher explained all test procedures, data collection methods and the purpose of the study to the participant. Participants were encouraged to ask question at any time during testing. A health history questionnaire was administered in order to ensure that all inclusion criteria were met and to identify any underlying medical complications. Resting values were taken as follows in accordance with *The Seventh Report of the join National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure* (JNC7), participants rested in the seated position for a period of 5 minutes before resting heart rate and blood pressure were measured. Heart rate was measured by palpating the radial artery and counting pulse beats for a period of one minute. Resting blood pressure was taken on the left arm, pending anatomical rational, by using an aneroid sphygmomanometer (Tycos 509 Welch Allyn Inc., Skaneateles Falls, NY). Two blood pressure measures were taken thirty seconds apart by a trained technician and averaged. Values greater than 6 mmHg in difference required a third reading to be taken for averaging. Two resting heart rates were taken following each blood pressure measurement as described above. Heart rate and blood pressure were taken on the left arm pending anatomical rational.

Height and weight were taken respectively by a standard wall stadiometer (Seca 216 Chino, CA) and digital floor scale (Health – O – Meter Professional 349KLX Sunbeam Products, Inc., McCook, IL.). Investigators instructed participants to remove shoes, heavy items and jewelry before measurements. Body mass index (BMI) was calculated by $(weight\ kg) \times$ - $(height\ m)^2$. Waist circumference ratio was determined in accordance to ACSM guidelines (2014) using a tape measure with spring-loaded handle. The narrowest point between the umbilicus and xiphoid process and widest point above the iliac crest were measured. Waist to hip ratio was determined by dividing waist and hip circumference measured in centimeters.

Trail Making Test and Stroop Task were given to participants in a private room free of distraction. Participants were instructed to complete both tasks as quickly as possible. Investigators recorded total time to perform part A and B separately for assessment. Mistakes by the participant in the sequencing task were corrected and figured into the total time to complete the task. Part A and B were administered separately with clear verbal instruction given by the researcher to the participant before each task. The test was placed upside down on a flat surface prior to being administered. Participants were not able to turn the test over until instructed to do so. Test timing began when the pencil was placed on the first item and ceased when the final item was marked. Participants were given an opportunity to ask questions regarding the task prior to task onset.

Stroop test cards were given to the participant in the form of a test booklet. Participants were not permitted to open or begin the test until the researcher gave instruction to do so. Cards were given on a flat surface. Participants were not allowed to rotate the cards more than 45˚ in either direction during the task or lift the card from the table. Participants were not allowed to cover any portion of the test item they were reading. Each of the three cards were issued separately as an individual task. Participants were given 45 seconds to read aloud as many items as possible Timing began when the first item was read aloud and stopped when the alarm from the alarm clock sounded. The final word read was then marked by the researcher. The following script was read to each participant prior to beginning the first task:

> ”*This is a test of how fast you can read the words on this page. After I say begin, you are to read down the columns starting with the first one until you complete it then continue without stopping down the remaining columns in order. If you finish all the columns before I say “Stop”, then return to the first column and begin*

again. Remember, do not stop reading until I say "Stop" and read out loud as quickly as you can. If you make a mistake, I will say "no" to you. Correct your error and continue without stopping. Are there any questions? Ready? Then begin. (After 45 seconds) Stop. Circle the item you are on. If you finished the entire page and began again, put a one by the circle."

The instructions were identical for all three cards with the exception that the participants were asked to name the word, color and color of the ink the words were printed in for cards I, II and III, respectively.

Accelerometry (ActiGraph Model GT3X tri-axial accelerometer; ActiGraph, Pensacola, Fl., USA) was used to assess free living physical activity. Participants were asked to wear the device over the right hip for a period of one week. The accelerometer was initialized for the participant using subject ID, gender, height, weight, DOB and race. Accelerometer sampling rates were standardized at 60Hz. Instruction was given by the researcher through verbal and written instruction. The researcher demonstrated where the device was to be worn over the right hip to the participant. Participants were asked to demonstrate how to attach the device to the researcher. The device was only to be removed during bathing, water activities and before going to bed each night. Each participant was supplied with an activity log sheet so that non-compliance, exercise and unusual activities could be documented over the seven day wear time period.

From the log sheet, MVPA activities that have been shown to be poorly detected through accelerometer were allocated to accelerometry measurements to determine total MVPA. This was done only in instances where mode, duration, and intensity were reported by the participant on the log sheet. Activity intensity was determined by using The Compendium of Physical

Activities where ≤ three metabolic equivalents (METs) were considered light/sedentary PA and ≥ three METs were considered MVPA (Ainsworth, 2004). Minutes of activity were then MVPAACC+ to accelerometer activity minutes. This was done by adding the total duration of time spent in a specific PA category to the accelerometer counts per minute derived from the device. As an example, one participant swam for one hour at a MET level > four METs. After analysis of activity measured by accelerometry, 60 minutes of MVPA were MVPAACC+ to the final total.

Visit Two. Participants returned the accelerometer to the Human Performance Laboratory after seven days of wear time. Researchers validated compliance criteria using ActiGraph software. If the criteria were not met, participants were asked to wear the device for an additional seven days. Wear time validation criteria were met if the participant wore the device for ≥ four days (three weekday and one weekend day) for ≥ 10 hrs. /day (Tudor-Locke et al., 2004). The International Physical Activity Questionnaire (IPAQ) was used to assess subjective physical activity over the seven day wear time period.

The IPAQ is a subjective activity recall questionnaire. The participant is asked four questions regarding his/her activity over the seven days which he/she wore the PA monitor. The questionnaire asks the participant to quantify days per week and hours and minutes per day spent doing vigorous, moderate, walking and seated activities.

Analysis. Accelerometer raw data counts were analyzed using ActiLife Software 6.8.0. Wear time compliance and mean counts/day were validated through the software. Participants were categorized as sedentary or adherent to MVPA based on activity counts/minute established by Santos-Lozanos and colleagues (2013) for older adults (age 60 – 85). The ACSM (2014) suggests that all adults participate in 150 minutes of moderate activity or 70 minutes of vigorous physical activity each week. These criteria were used to determine physical activity classifications. All counts/minute greater than the established threshold of > 2,751 counts/minute were considered MVPA. Sedentary counts were categorized by periods of immobility greater than 30 minutes. Sedentary activity consisted of counts less than MVPA threshold. In this way, older adults were considered to be physically active or physically inactive.

Trail Making Test Part A (TMTa) and B (TMTb) were timed for completion where scores represent the amount of time required to complete the task. Performance on TMTa and TMTb was compared to normative data established by Tombaugh (2004) with age and education taken into account. Based on this research, percentile scores were assigned to each participant based on age group and education level. These adjusted percentiles as well as raw scores were included in analysis.

Stroop Task was scored based on color (C), word (W) and color-word (CW) item scores each determined by number of items read out loud in the 45 second time limit. C and W scores were used to predict CW scores. The difference between actual CW scores and predicted CW scores were used to determine the participants' interference score where interference is the product of word and color scores divided by the sum of word and color scores. Residual scores which account for age and education were used in accordance to population norms reported by Golden and Freshwater (2002).

Statistical Analysis. To examine the relationship between PA and cognitive function test outcomes in older adults multiple cognitive performance tasks and an objective PA monitor were used. To measure this association, Stroop Task and TMT were used to assess cognitive performance. Sedentary/light PA and MVPA minutes per week were measured using the ActiGraph Model GT3x tri-axial accelerometer (ActiGraph, Pensacola, FL, USA). Threshold ranges were established between activity categories as described by Santos-Lozanos and colleagues (2013) for older adults.

Statistics. Correlation analysis was used to test the relationship between PA and cognitive function. Objective and subjective MVPA measures were compared to each cognitive performance task outcome (Stroop W, Stroop C, Stroop CW, TMTa and TMTb) as well as other PA variables. Pearson's product moment correlation and significance were reported for these comparisons. T-tests were run to examine the relationship between physically active and physically inactive groups and effect sizes were reported using Cohen's d test. Data analysis was performed using SPSS version 20 for Windows (SPSS Inc., Chicago, IL). Cohen's d effect sizes were determined through an online calculator. Significance was set at the $p < 0.05$ level for all statistical tests.

Results: The study group included 35 older adults (mean 70.6 ± 4.6 years). Weekly MVPA as measured by accelerometry ($MVPA_{ACC+}$) was found to correlate significantly with W ($p = < .05$, $r = .446$), C ($p = < .05$, $r = .389$) and CW ($p = < .05$, $r = .609$) performance outcomes. $MVPA_{ACC+}$ was also found to have a significant relationship with TMTb outcomes ($p < .05$, $r = -.358$). $MVPA_{ACC+}$ was not found to have a significant relationship with TMT difference scores ($p = .054$, $r = -.349$). Objectively measured Sedentary/light PA ($\text{Sedentary/light}_{ACC}$) did not demonstrate a significant relationship with W, C, and CW task scores ($p = .73$, $r = .061$; $p = .68$, $r = - .073$; $p = .95$, $r = .011$, respectively).

Self-reported weekly MVPA ($MVPA_{IPAQ}$) as determined by IPAQ questionnaire was not statistically significant when compared to W ($p = .09$, $r = .316$), C ($p = .80$, $r = .047$), CW ($p = .13$, $r = .282$) and TMTb ($p = .51$, $r = -.124$) cognitive performance measures. $MVPA_{ACC+}$ and $MVPA_{IPAQ}$ were shown to be correlated ($p < .05$, $r = 0.521$) whereas sedentary/light PA did not show a relationship between Sedentary/light$_{ACC}$ and self-report sedentary/light PA (Sedentary/light$_{IPAQ}$) values ($p = .08$, $r = .675$). Total steps/week were strongly correlated to total MVPA$_{ACC+}$ ($p < .05$, $r =.752$). Energy expenditure was related with cognitive performance where W ($p = <.05$, $r = .416$), C ($p = < .05$, $r = .424$), CW ($p = < .05$, $r = .656$), TMTb ($p = < .05$, $r = -.532$) and TMTdiff ($p = < .05$, -.485) were significant. Table 4.2 provides correlation values for all variables considered.

No differences were indicated between men and women when compared to weekly MVPA$_{ACC+}$ ($p = .406$), MVPA$_{IPAQ}$ ($p = .295$), CW scores ($p = .771$) or TMT difference scores ($p = .236$). Women were shown to have a stronger relationship between MVPA$_{ACC+}$ and TMTb performance ($p < .05$, $r =.732$) when compared to men ($p = .20$, $r = .432$). Age did not show a significant relationship with MVPA$_{ACC+}$ ($p = .43$, $r = .144$), MVPA$_{IPAQ}$ ($p = .28$, $r = .124$), CW scores ($p = .72$, $r = -.062$), TMT difference ($p = .43$, $r = .137$) or TMTb ($p = .13$, $r = .26$). However, age was noted to have a significant correlation with TMTa scores ($p < .05$, $r =.418$).

Statistical analysis indicate that those older adults participating in > 150 minutes of MVPA weekly perform better on cognitive performance tasks. Independent samples t-tests suggest that those accumulating MVPA in accordance to ACSM guidelines performed better on W ($p = .003$, $r = .283$, $d = -.61$), C ($p = .001$, $r = .444$, $d = -.65$) and CW ($p = .015$, $r = .768$, $d = -.48$) cognitive performance outcomes. TMT difference scores were not indicated to have a similar relationship with MVPA time ($p =.241$, $r = .000$, $d = .14$). T-test significance and effect sizes reported in Table 4-3.

Discussion: Eleven participants reported PA minutes from exercise modes which were not detected by accelerometry (Bassett, 2000). In order to best capture weekly PA for these individuals, subjectively recorded PA minutes were MVPAACC+ to accelerometry totals. For purposes of interpretation, it is important to note that total Sedentary/light$_{ACC}$ and MVPA$_{ACC+}$ were allocated for these 11 participants according to aforementioned methods. For six of these participants' additional PA minutes for poorly detected modes were obtained through their local fitness center where an exercise specialist recorded mode, duration and intensity of the activity. As an example, one participant reported free-style lap swimming on four of the seven recorded days for a period of one hour per session. The Compendium of Physical Activities was used to determine intensity based on time and distance swam. Likewise, this method was implemented individually for each of the eleven participants. Intensity was determined from metabolic equivalents (METs) where ≤ three METs are considered sedentary/light PA and ≥ three METs are considered MVPA (Physical Activity Guidelines Advisory Committee Report, 2008). An average of 31 ± 35.6 minutes of PA minutes were MVPAACC+ to MVPA$_{ACC+}$. These additions to MVPA totals should be considered for interpretation of MVPA totals as measured by accelerometer. It is thought that in the absence of this technique the strength of relationship between PA and cognitive function would be improved, as the distribution of scores would be greater.

Results from the current study demonstrate better cognitive performance outcomes as measured through Stroop Color and Word Test among more physically active older adults when compared to less active peers (Figure 4-1). Specifically, cognitive function tasks of inhibition and shifting seem to be improved by PA in the group. MVPA$_{ACC+}$ predicted Stroop W, C, and CW performance outcomes and explained 20, 15, and 37% of the relationship, respectively. In line with extant research, the typical pattern for all participants presented as diminished raw item scores through task progression from C, W, and CW reciting tasks, respectively (Stroop, 1935). Residual interference scores were used for scoring in order to correct for differences in age and education.

Low scores for the Stroop W task have been found to indicate possible motor-speech problems, learning disability or low education level. Where low scores reflect poor reading ability speech is observed to be fluent but slow throughout the task (Golden & Freshwater, 2002). This was the case for two of the study participants. In addition, one participant was observed to have a low W score attributed to testing being done in their second language. This offers explanation to documented low W scores in the presence of high $MVPA_{ACC+}$.

Diminished Stroop C task scores suggest a problem identifying color names or color blindness (Golden & Freshwater, 2002). In some cases, low C scores, in conjunction with low W scores indicate low intelligence. However, this was not thought to be the case in the current study as W and C scores were found to be within consistent limits. In cases where low intelligence is not indicated it is thought that consistent but low W and C scores could be attributed to poor effort. Stand-alone low C scores can be indicative of cognitive defects.

Low value CW scores presented where W and C scores are normal indicate interference. For the current study, interference is used as a primary indication of cognitive decline and pre-frontal pathology. On the other hand, CW t-scores significantly better than C and W t-scores suggest strong ability of the participant to inhibit the conflicting responses (Golden & Freshwater, 2002). In this way, interference is used as an indication of poor or high cognitive functioning ability. In the same way CW scores in conjunction with normal W and C scores indicate cognitive interference.

$MVPA_{ACC+}$ was also significantly correlated with performance on TMTb indicating trends of improved attention and shifting abilities among physically active older adults (Figure 4-2). Findings were consistent with normative data sets (N=911) adjusted for age and education by Tombaugh (2004) who produce percentile scores based on participant age and education level. To the researcher's knowledge, no research has yet evaluated the relationship between free-living PA and TMT outcomes. The importance then of assessing the role of $MVPA_{ACC+}$ on cognitive task outcomes is promising as TMT is often associated with multiple executive function variables including visual searching, scanning, speed of mental processing, and mental flexibility (shifting). Consequently, it is promising that despite small sample sizes $MVPA_{ACC+}$ was shown to significantly account for 13% of the correlation. $MVPA_{ACC+}$ however was not shown to have a relationship with TMT difference scores (time difference between TMTa and TMTb). It is proposed that due to the higher education of the present participants difference in scores were not substantial. Additionally, pre-test screening was purposed to finding a cognitively healthy group and thereby it is thought that strong task performance produced consistent results between TMTa and TMTb. Finally, the small sample size was also a factor for consideration of why TMT difference scores were not significantly linked to PA level.

Evidence from the current study is in line with extant literature (Eggermont et al., 2009; Po-Wen., et al. 2012; van Gelder et al., 2004). The principle difference in this study design was the inclusion of accelerometry to assess the possible relationship between PA and cognitive function. In a prospective study of PA and cognitive function conducted by Yaffe and colleagues (2001) 5,925 women free of clinical cognitive impairment demonstrated superior cognitive performance than those reporting lower PA levels. PA was determined by having the participant predict how many city blocks they had walked in the past week. From this prediction distance and energy expenditure were estimated. Likewise, Larson and team (2006) showed that men and women who exercised fewer than three times per week were at increased risk of dementia incidence (19.7 per 1000 person years) than their more physically active peers (13.7 per 1000 person years). PA was evaluated through self-report. Researchers then estimated energy expenditure from participant recall. These findings help strengthen the current research as similar outcomes were used and most importantly due to the indication that increased PA strengthens cognitive performance.

Instead of participants' recall, accelerometers in this study facilitated objective measurement of energy expenditure (kilocalories). The accelerometer in this study (ActiGraph GT3x, Pensacola, FL., USA) was validated against indirect calorimetry and uses individualized weight (kg.) to estimate energy expenditure. Unlike extant research where energy expenditure was grossly estimated (van Gelder., 2004; Yaffe et al, 2001), accelerometry accounts for variables necessary to validate estimations (i.e. weight and activity intensity). In the current study, kilocalories expended in the week as measured by accelerometry correlated strongly with time spent in $MVPA_{ACC+}$ activities at the $p < .05$ level. Not surprising then is the indicated positive relationship found between energy expenditure and cognitive function tasks, namely Stroop CW ($p < .05$, $r = .656$) and TMTb ($p < .05$, $r = -.532$). These findings are consistent with previous studies where increased energy expenditure correlates with improved cognitive function outcomes (Boucard et al., 2012; Kramer, 2006; Yaffe et al., 2001)

In fact, few studies have used accelerometers in older populations (Copeland & Esliger, 2009; Davis & Fox, 2007). Early studies comparing the PA outcomes of older and young adults as measured by accelerometers failed to address differences in physical capacity between these groups. Davis and Fox (2007) identified older populations as being nearly 40% less active than their young adult counterparts. The fundamental problem with this conjecture hinges on the assumption that PA intensities for similar tasks are identical for older and younger populations. Copeland and Esliger (2009) addressed this problem by establishing accelerometer cut-points for older adults. By use of indirect calorimetry, Copeland and Esliger objectively identified intensity thresholds for the older adult population thus eliminating the assumption that even nominal tasks require the same energy expenditure as younger cohorts. Because activity counts had not yet been established, it is proposed that early accelerometer studies with older adult cohorts grossly under-estimated PA patterns. Limitations of early accelerometer generations made Copeland and Esliger's contention difficult to prove. It has since been demonstrated that older generation GT1M ActiGraph uni-axial accelerometers (ActiGraph, Pensacola, FL, USA), used by Copeland and Esliger in their 2009 report, overestimate activity counts when compared to GT3x tri-axial contemporaries (Sasaki, Dinesh & Freedson, 2011). Therefore, these counts often overestimated activity patterns among older adults. Where prior activity count thresholds under estimated older adults activity due to diminished physical capacity, older generation accelerometers over compensated and provided activity counts that were unrealistically high for this group.

Recently, Santos-Lozano (2013) established activity counts for the newer generation GT3x accelerometer. The introduction of these cut points allows researchers to more accurately assess the PA and energy expenditure of older adults. Threshold counts > 99 counts/minute and < 2,150 counts/minute were used to identify sedentary and light PA. Vector magnitude counts > 2,151 per minute categorized activity as the threshold for MVPA. The current study used these thresholds to determine PA frequency, duration and intensity.

The current study sought to strengthen the PA and cognitive function relationship by eliminating potential recall bias and the social desirability often associated with self-report PA questionnaires (Sallis & Saelens, 2000). An additional problem with self-report PA information is the inability to determine intensity of activities. Subjective assessments of PA and intensity are unreliable and especially difficult to use for sensitive comparisons such as cognitive function. Importantly, the potential influence of intensity on cognitive function performance can only be attained through objective methods. Although subjective methods were used to improve the accuracy of MVPA minutes for some subject these accounts were confirmed by objective methods and implemented only in instances of precise duration, intensity and activity mode information.

The use of accelerometry was further recommended by Troiano and colleague's (2008) interpretation of the National Health and Nutritional Examination Survey (NHANES). From the NHANES cross sectional study researchers were able to obtain objective PA data as measured by accelerometry from > 6,300 participants. These findings point toward the increasingly popular assessment of PA by objective devices but most importantly Trioiano and colleagues identified three key conclusions. First, objective and subjective measures provide similar patterns of activity between gender and age groups. Second, the adherence to PA recommendations according to objective accelerometer findings was significantly less than when compared to self-report values. Finally, self-report PA information requires great care of analysis and interpretation within the scopes of clinical, public health and epidemiological practice. The first two findings are consistent with observations and indications from the present study and are encouraging given the relatively small sample size compared to NHANES data. This may indicate to the plausibility of the present study for assessing PA and cognitive performance.

Boucard and colleagues (2012) concluded similar findings to the present study where inhibition was indicated to be correlated with MVPA but cognitive tasks of shifting were not.

The present study indicates relationships between both cognitive variables. The reason for the discrepancies between Boucard's study and the present study is thought to be twofold. First, Boucard and colleagues limited PA assessment to two days of monitoring. Secondly, participants were instructed to wear the device on their most active and inactive days. This is a problematic approach in that it turns objective assessment methods into a subjective approach. As previously discussed, Boucard and colleagues used activity counts that have been shown to be inappropriate for PA assessment in older adults (Copeland & Esliger, 2009; Sasaki, Dinesh & Freedson, 2011; For these reasons it is proposed that the assessment of cognitive function tasks with PA as the independent variable would have likely indicated lower activity thresholds for older adults. Subjectively selected wear time validation by the participants instead of objectively interpreted by researchers in line with current accelerometer wear time procedure selections (Tudor-Locke, 2004) would then render the data unusable for dose-response counsel. Previously, Tudor-Locke (2004) proposed that activity patterns between days of the week differ significantly, thus suggesting the importance of consecutive days of activity monitoring. The current study attempted to strengthen this approach by using seven concurrent days of objective assessment with a minimum of 10 hours per day necessary for assessment. This way it was hoped that at least four valid days of assessment would be gathered including three weekdays and one weekend day in line with extant literature. Despite potential gaps in PA pattern practice, Boucard and colleagues (2012) approach to measuring cognitive function performance was emulated by using multiple cognitive performance tasks to determine function of specific cognitive tasks.

The present study also used the IPAQ for subjective PA reporting for comparison to previous research which assessed PA with subjective methods. No statistically significant relationship was observed when $MVPA_{IPAQ}$ reports were compared to Stroop CW ($p = .09$, $r = .316$) and TMTb ($p= .51$, $r = -.124$). Sedentary/$light_{IPAQ}$ did not show significance to Stroop CW ($p = .26$, $r = .214$) and TMTb ($p= .38$, $r = .165$), either. $MVPA_{IPAQ}$ only accounted for 10, .2 and 7% of the variance for Stroop W, C and CW scores, respectively. Similar values were found when comparing $MVPA_{IPAQ}$ to TMTb and TMT difference where 1 and 5% of the variance were explained. Previous research has reported correlation between self-report PA and cognitive function. Ku, Stevinson and Chen (2012) reported significant association between higher levels of PA and cognitive performance (standardize coefficient $\beta= 0.17$) among 1,160 older Taiwanese adults (age > 67 years). Likewise, results from Ku, Stevinson and Chen are consistent with previously mentioned research from Yaffe and colleagues (2001) wherein 5,925 women over the age of 65 were shown to have superior cognitive performance scores with increased self-report PA levels. These results are not consistent with the current study. This is likely because of the smaller study size of the current study when compared to the aforementioned studies.

The use of different subjective PA report tools may explain the observed discrepancies between the current study and previous research. Different instruments qualify PA uniquely and may lead researchers to interpret these reports with variance. The IPAQ has been shown to be a reliable and valid measure of PA (Craig et al., 2003). However, it has been documented that older adults overestimate the level of exertion associated with PA (Copeland & Esliger, 2009). The IPAQ classifies PA into four categories including vigorous, moderate, walking and sitting activities. The distinction between moderate and vigorous is subjective and furthermore the classification between walking around the home or walking for health and fitness are undistinguishable to many. For this reason the difference in self report MVPA between studies may be observed.

An additional consideration to subjective PA reports are the length of time and complexity of recall questioning. To the credit of the IPAQ the recall time is limited to the week over which the PA monitor was worn making it a feasible tool. Many subjective instruments inquire about activity over the lifespan or over several years (Shephard, 2003). For the present study the IPAQ served as a complement to objective monitoring to benefit analysis. Statistical analysis did not show significant association between Sedentary/light$_{ACC}$ and Sedentary/light$_{IPAQ}$ but did indicate that MVPA$_{ACC+}$ and MVPA$_{IPAQ}$ were positively associated However, even though the relationship is positive, MVPA$_{IPAQ}$ was shown to grossly overestimate or underestimate PA for most participants.

Self-report PA instruments are thought to be appropriate tools for identifying activity trends among large groups but do not provide accurate measures of activity intensity or energy expenditure. In line with the study in consideration, Barnes and colleagues (2003) used both objective and subjective PA instruments to assess 349 men and women over the age of 55 years. They found a significant inverse relationship between objectively based PA assessment and cognitive function. Conversely, no relationship was found when using subjective assessments. This supports the findings of the present study where PA intensity is thought to be a substantial factor in cognitive function performance as evident by the significant relationship noted between energy expenditure in kilocalories and Stroop CW and TMTb performance outcomes.

Of further importance, in the present study, total steps taken showed a strong correlation with MVPA$_{ACC+}$. This indicates the potential use of other objective monitors, namely pedometers, to determine the influence of PA on cognitive function. Only one cognitive performance study has used objective monitors to quantify PA. Lautenschlager and colleagues (2013) randomly assigned 138 participants over the age of 50 to intent to treat PA and control groups. Using pedometers, they categorized the cohort as either PA or PIA based on a 70,000 set/week threshold. This measurement was taken throughout a 24-week PA intervention period. Participants in the intervention group accrued more steps/day than the control group and were found to perform superior on cognitive tasks. This observation is consistent with the relationships noted in the present study. The group observed in the present study averaged 44,528 steps/week, less than the proposed 70,000 steps/week threshold used by Lautenschlager and colleagues Lautenschlager and colleagues used the 70,000 steps/week threshold because of documented evidence of improving health benefits associated with 10,000 steps/day. The purpose of the present study was only to examine correlations with cognitive performance not causal relationships which might have been observed during the intervention period in the reference study. More steps/week may indicate increased PA but are not valid determinates of intensity of activities (Harris et al., 2009). Accelerometers are then preferred over pedometers because of their direct ability to detect relationships with PA intensity.

In the present study, no statistical differences between men and women were observed when grouped by $MVPA_{ACC+}$, $MVPA_{IPAQ}$, Stroop W, Stroop C, Stroop CW or TMT difference scores. Women demonstrated a stronger relationship between $MVPA_{ACC+}$ and TMTb. This is thought to be related to the difference in group sizes between men (n= 21) and women (n= 14). Additionally, it is thought that women may pursue lower intensity activities when compared to men and therefore display a tighter relationship with normal TMT scores. Differences between men and women were not anticipated for Stroop task scores as previous research confirms reliable similarities between gender groups (Golden & Freshwater, 2002).

The relationship between $MVPA_{AAC}$ and Stroop CW was stronger than that of $MVPA_{ACC+}$ and TMT scores. This is thought to be due to the increased sensitivity of the Stroop task. Stroop task accounts for education status and age for reported residual t-scores. Because of this correction, and the higher education status of the cohort studied, these scores may have been closely related and thus demonstrating a homogenous sample.

Non-significance of the TMT difference test was not surprising as the study looked at a cognitively healthy group. Therefore, TMTb and TMT difference scores were similar indicating a small distribution of scores for comparison to MVPA. Additionally, the group was thought to be more physically active than national averages may indicate for older adults (Davis & Fox, 2007; Harris, 2009) also contributing to narrow distributions for correlation scores.

Within the current study all participants possessed, at minimum, a high school education. Importantly, it should be noted that this population represent a small homogenous population of older adults due to high mean education status (17 ± 2.8 years). Likewise, mean PA (256 ± 89 minutes) was also reportedly high in comparison to previous studies of this cohort (Harris, 2009). Shaw and Spokane (2008) reported steeper age-related declines in PA among low-education level older adults in N=7,595 older adults between the ages of 54 – 73 years. The current study supports these findings. For this reason, it is proposed that the current sample of older adults is considered to be more physically active due to the association with higher education levels. Due to the recruitment throughout Muncie, IN and the strong interdependent relationship with the local University, the study sample is a reasonable representation of older adults within the community, but not of all older adults. Interpretation of these results must be proceed with this caveat.

Despite the higher education and PA status of the current group and the reasonable correlations supporting physical activity's relationship with cognitive performance, it is thought that a demographic with a larger distribution of education and PA would strengthen the relationship. Currently results therefore are meaningful with consideration of the current strength of relationship being shown within this small and cognitively healthy group (Figures 4-1 and 4-2). Less physically active and lower education participants would have improved correlations by providing a more generalized spread of data for analysis.

An exploratory purpose of this study was to evaluate potential differences in cognitive function outcomes between men and women accumulating the minimum suggested MVPA per week according to ACSM guidelines (Nelson, 2007). Drawing upon the results from independent samples t-tests herein, it seemed as though accumulating MVPA in accordance to these guidelines was associated with better performance on Stroop W, C, and CW tasks. Although this trend is indicated, it is important to note that within the group of 31 used for analysis, only seven individuals did not accumulate 150 minutes of MVPA as measured by Santos-Lozanos (2013) activity counts created for older adults. Cohen d effect sizes indicate moderate effect sizes for Stroop tests, however, the spread of group means must be considered in interpretation (Table 3). However, given positive and significant trends found between $MVPA_{ACC+}$ and cognitive performance variables joint with the indication of this relationship between groups of those attaining or not attaining 150 minutes of MVPA it is reasonable to infer that this threshold may be a marker of benefit for cognitive function performance.

Limitations: Major limitations to the present study include its relatively small and homogenous sample size (N=32) as well as an unequal distribution of physically active to physically inactive participants (n=25 n=7) which affect the generalizability of these findings. Cross-sectional designs only provide a snap-shot of the population making identification of causal relationships inaccessible. Questions of the current study are then directed at the influence PA has on cognitive performance. Given the indicated relationships, the meaning of these results would be better substantiated if the duration, frequency and habitual nature of PA could be assessed. Additionally, given that the data collection occurred within a college campus and college town, participants to the current study may have been particularly highly educated. This said, efforts to eliminate confounds of education by use of residual t-scores for Stroop and TMT tasks were made therefore this potential confound may have not had a profound impact on the current results. A further limitation to the present study included the lack of extant research regarding older adults and use of accelerometer methods. For this reason, the interpretation of PA patterns must be clarified and interpreted with reference to Santos-Lozanos (2013) cut points for older adults. The study was also limited by the availability of cognitive performance tasks. Finally, visual acuity was a factor for several participants when trying to perform written and verbal cognitive tasks. Inability to read smaller print and clearly identify colors may have influenced the results of some of the participants herein.

In order to address these limitations future studies would benefit from larger, randomized samples tested within longitudinal and random control trial designs. Greater diversity of samples would highly benefit the present findings. Recruitment of older adults from different geographic regions would also ensure generalizable findings. Since few studies have considered the use of accelerometer activity counts for older adults it is important that a consensus be found among researchers evaluating PA via use of these devices in this cohort. It can therefore be beneficial to use activity counts specifically designed for older adults instead PA cut points previously designed for younger adults in order to normalize PA interpretation. In addition, more sensitive cognitive performance measures should be used to better determine cognitive performance outcomes in line with existing literature (Boucard et al., 2012; van Gelder et al., 2004). Finally, vision problems which can affect cognitive test outcomes can be easily corrected by pre-screening participants for such conditions or disease.

Strengths: Strengths of the current study include use of accelerometers. It is important that PA patterns be accurately assessed to facilitate meaningful implications in this population. Moreover, older adults often misinterpret activity intensities due to diminished physical capacity leading to overestimates of PA (Copeland & Esliger, 2009, Troiano, 2008). Additionally, recall instruments are subject to recall bias and rely on memory to categorize PA (Sallis & Saelens, 2000; Shephard, 2003), and using accelerometers solves these potential complications. Although subjective log sheets were used to add to MVPA minutes these reports were controlled by other objective methods or only where duration, intensity and type of activity were reported. Another potential strength of the current study is that multiple cognitive function assessments were used to test performance. Using multiple instruments allows for researchers to better interpret cognitive performance results by looking at multiple cognitive performance task outcomes which target specific outcomes.

Implications: Implications of the current study include the recommendation for older adults to achieve PA frequency, duration, intensity and energy expenditure consistent with current national guidelines (Nelson et al., 2007). Consistent with previous research, increased PA participation would benefit older adults in decreasing disease and mortality risk, improving stability, decreasing fall risk and bettering health and quality of life (Blair et al., 2001; Paffenbarger et al., 1994). Of specific interest herein, PA may exert a positive effect on cognitive function in this population. Accordingly, fitness experts can strive for designing regimens to increase PA participation in this population and regularly assess the effectiveness of these via use of objective measures (i.e., accelerometers). Results from this study further provide a rationale for the use of objective PA measurements to strengthen future research directives. As such, use of established accelerometry methodologies will allow for valid assessments of the potential causal relationship between PA intensity and cognitive function performance in older adults. Therefore, these methods should ideally be included in all PA interventions and long-term evaluations of cognitive function.

Table 4-1
Descriptive Characteristics of Sample Variables

Variable	*Mean ± SD*
Edu (years)	17 ± 2.8
Age (years)	70.57 ± 4.5
BMI $(kg/m)^2$	26.5 ± 4.0
Weight (kg)	76.9 ± 14.3
TMTa (sec.)	31.2 ± 10.3
TMTa (%tile)	70 ± 30%
TMTb (sec.)	70.8± 26.4
TMTb (%tile)	70 ± 30%
TMT (diff.)	40.8± 21.4
Stroop W (t-score)	44± 10.1
Stroop C (t-score)	45.6 ± 10
Stroop CW (t-score)	48.5± 5.4
Kcal per week	1,784 ± 5,710
$Sed/Light_{AAC}$ (min./wk.)	5,680 ± 1,298
$MVPA_{ACC+}$ (min./wk.)	256 ± 89
$Sed/Light_{IPAQ}$ (min./wk.)	4,464 ± 3,310
$MVPA_{IPAQ}$ (min./wk.)	540 ± 727
Steps (/wk.)	44,527 ± 11,609

SD, Standard Deviation; Edu, education; BMI, body mass index; TMTa, Trail Making Test part A; TMTb, Trail Making Test part B; TMT diff, TMT a & b difference; Stroop W, Stroop Word score; Stroop C, Stroop Color score; Stroop CW, Stroop Color-Word score; kcal, kilocalorie; $Sed/Light_{ACC}$, Sedentary/Light accelerometer counts; $MVPA_{ACC+}$, moderate to vigorous Physical Activity accelerometer counts; $Sed/Light_{IPAQ}$, Sedentary/light IPAQ minutes/week; $MVPA_{IPAQ}$ moderate to vigorous physical activity IPAQ minutes/week.

Table 4-2

Correlation Table of Participant Sample Variables

Variable		Pearson Moment Correlation	Significance
$MVPA_{ACC+}$			
	W	.446	.01*
	C	.389	.03*
	CW	.609	.00**
	TMTa	-.183	.32
	TMTb	-.358	.04*
	TMTdiff	-.349	.05
	$MVPA_{IPAQ}$	.521	.00**
	$Sed/Light_{ACC}$	.290	.10
	$Sed/Light_{IPAQ}$	.343	.08
	Steps/week	.752	.00**
	Kcal/week	.882	.00**
$MVPA_{IPAQ}$			
	W	.316	.08
	C	.047	.80
	CW	.282	.13
	TMTa	.112	.55
	TMTb	-.124	.51
	TMTdiff	-.232	.22
Kcal/week			
	W	.416	.02*
	C	.424	.02
	CW	.656	.00**
	TMTb	-.532	.00**
	TMTdiff	-.485	.00**
Age			
	$MVPA_{ACC+}$	.144	.43
	$MVPA_{IPAQ}$	.287	.12
	CW	-.062	.724
	TMTa	.012	.01*
	TMTb	-.028	.87
	TMTdiff	.137	.43

Note: *p < .05; **p < .01; TMTa, Trail Making Test part A; TMTb, Trail Making Test part B; TMT diff, TMT a & b difference; Stroop W, Stroop Word score; Stroop C, Stroop Color score; Stroop CW, Stroop Color-Word score; kcal, kilocalorie; $Sed/Light_{ACC}$, Sedentary/Light accelerometer counts; $MVPA_{ACC+}$, moderate to vigorous Physical Activity accelerometer counts; $Sed/Light_{IPAQ}$, Sedentary/light IPAQ minutes/week; $MVPA_{IPAQ}$ moderate to vigorous physical activity IPAQ minutes/week.

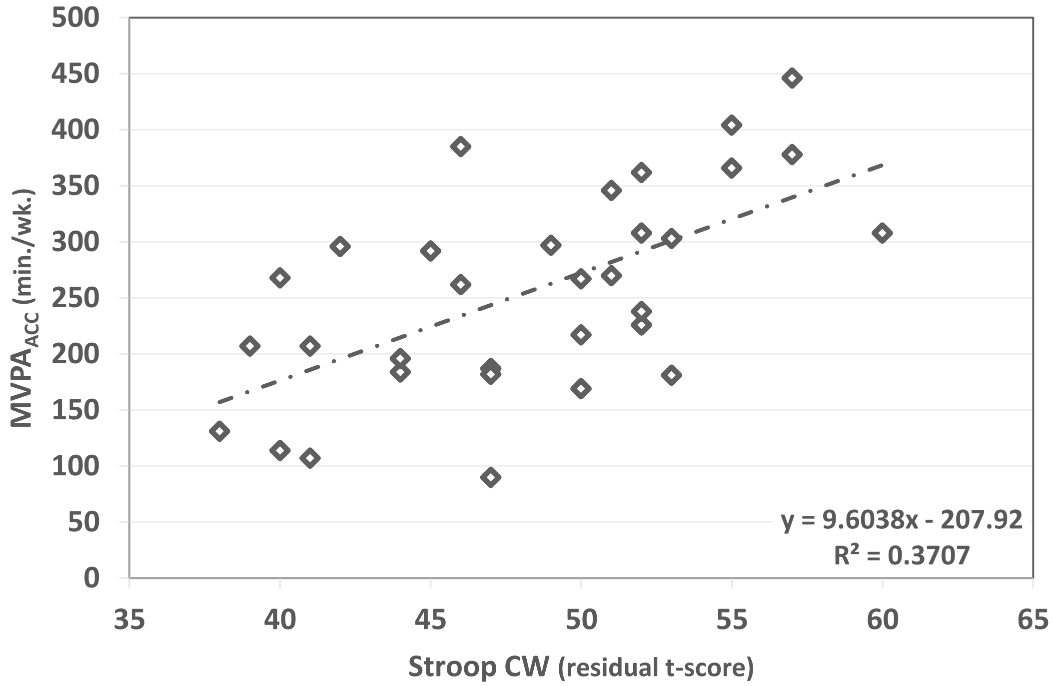

Figure 4-1. Relationship between Stroop CW t-scores and $MVPA_{ACC+}$ minutes accumulated per week.

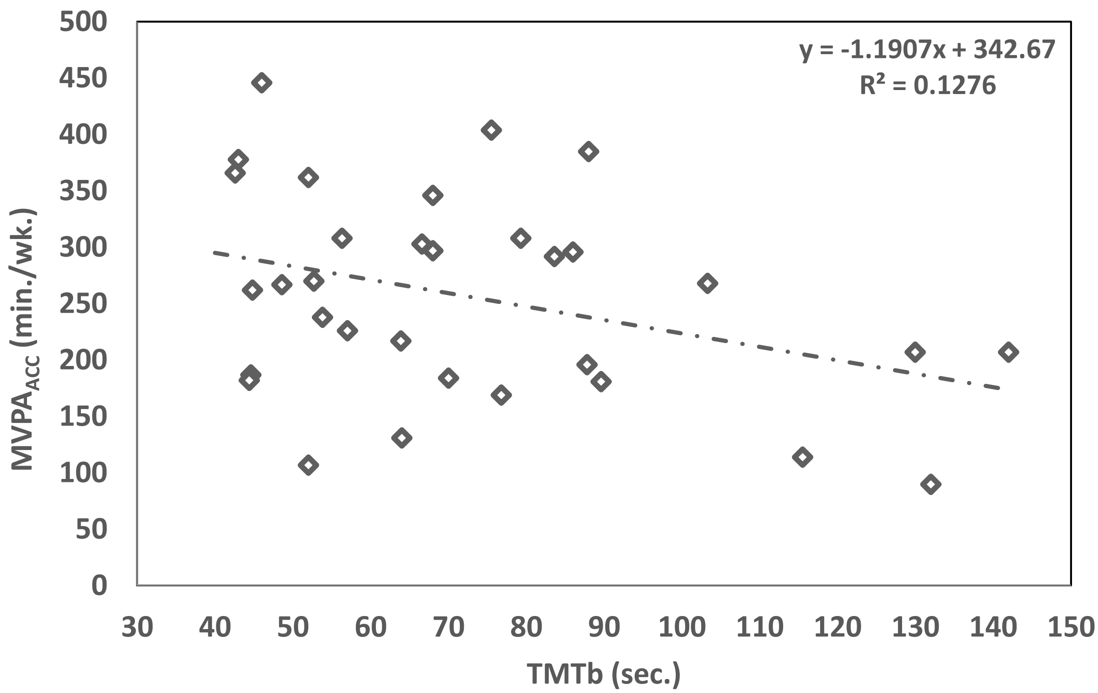

Figure 4-2. Relationship between TMTb and $MVPA_{ACC+}$ minutes accumulated per week.

Table 4-3

Differences between PA and PIA groups as categorized by 150 minutes of MVPA threshold.

	Group PIA	***Group PA***	***Effect size***
TMTa (sec.)	34.77 ± 9.25	30.8 ± 11.24	.19
TMTb (sec.)	91.43 ± 39.43	68.22 ± 21.5	.34
TMT diff (sec.)	56.61 ± 35.07	39.04 ± 15.91	.31
W	34 ± 7.28	47.46 ± 9.98*	.61
C	34.57 ± 7.53	48.63 ± 8.99*	.65
CW	43.57 ± 5.53	49.54 ± 5.3*	.48

Group results reported as mean ± standard deviation. * $p < .05$; PIA, physically inactive; PA, physically active; TMTa, Trail Making Test part A; TMTb, Trail Making Test part B; TMT diff, TMT a & b difference; Stroop W, Stroop Word score; Stroop C, Stroop Color score; Stroop CW, Stroop Color-Word score

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Chapter 5: Summary and Conclusions

Evidence suggests that dementia is closely linked to higher incidences of all-cause mortality risk factors such as diabetes, midlife hypertension, obesity, depression, PIA, smoking and lower education (Barnes & Yaffe, 2011; Eggermont, 2009, Newman et al., 2007; Whitmer et al., 2005). With this said, older adults experience the highest occurrence of dementia disease due to these increased risks (Wortmann, 2012). However, PA has been shown to have a strong inverse dose-response relationship with all aforementioned risk variables (Ferrucci et al., 1999; Haskell et al., 2007; Kesaniemi et al., 2001; Tanascescu et al., 2002). Despite this evidence older adults remain the most physically inactive cohort of any group.

Dose – response counsel exists highlighting the benefits of PA on many health and comorbidity risk factors. Current guidelines emphasize the importance of at least 30 minutes each day or a weekly total of 150 minutes of MVPA to be the evidence supported activity threshold for improving health (Haskell et al., 2007; Nelson et al., 2007). Yet, primary prevention recommendations have not been established regarding the role of PA on mental health due in large part to the infancy and inconsistencies of cognitive performance and PA research. Longitudinal and meta-analyses studies have identified a relationship between PA and cognitive performance but reports vary widely due to discrepancies in PA methodology (Colcombe & Kramer, 2003; Kramer, 2006; Sofi, 2010).

Therefore, the purpose of this study was to objectively assess the relationship between PA and cognitive performance in older adults. A secondary exploratory purpose was to determine if a difference in cognitive performance exists when comparing those fulfilling current ACSM PA guidelines and those who are not.

Results from the study suggest a significant relationship between PA and cognitive function outcomes. Specifically, it was observed that those with higher levels of objectively measured MVPA performed better on Stroop W ($p < .05$, $r = .446$), C ($p < .05$, $r = .389$) and CW ($p < .05$, $r = .609$), as well as TMTb ($p < .05$, $r = -.358$) performance outcomes when compared to less active peers. Subjective MVPA reports did not show a significant relationship with W ($p = .09$, $r = .316$), C ($p = .80$, $r = .047$), CW ($p = .13$, $r = .282$) or TMTb ($p = .51$, $r = -.124$). Sex and age did not have a significant impact on cognitive performance test outcomes. A relationship between objective and subjective MVPA was observed ($p < .05$, $r = .521$) as measured by accelerometry and IPAQ respectively. However, participants inconsistently reported PA when activity time was compared to objective analysis leaving the validity of this relationship in question.

Analysis further indicates that those older adults participating in > 150 minutes of MVPA weekly perform better on cognitive performance tasks. Independent samples T-tests suggest that those accumulating MVPA in accordance to ACSM guidelines performed better on W ($p = .003$), C ($p = .001$) and CW ($p = .015$) cognitive performance outcomes.

Due to the small homogenous sample size and the cross sectional study design, conclusions are limited in offering causal inference. Nonetheless, significant relationships between PA and cognitive function by use of objective PA assessments and multiple cognitive performance tasks are encouraging and warrant future exploration. The successful objective evaluation of PA patterns in older adults can be better implemented in future cognitive function assessment studies in hopes of better identifying suspected causal effects of PA on cognitive health. In so doing a better picture of PA can be given and causal relationships can be better understood.

Future directions. Future studies would benefit from larger, randomized samples tested within longitudinal and random control trial designs. Recruitment of older adults from different geographical regions would ensure generalizable findings. Since few studies have made use of accelerometer activity counts for older adults, it is important that a consensus be reached among researchers evaluating PA in this cohort. Future studies will benefit from using these PA assessment methodologies when comparing effectiveness of differential interventions and/or determining the maintenance of these in the long run. In addition, more sensitive cognitive performance outcomes should be used to better determine cognitive performance outcomes in line with existing literature (Boucard et al., 2012, van Gelder et al., 2004, Yaffe et al., 2001). Relevant practical implications include important recommendation for older adults to achieve PA frequency, duration, intensity and energy expenditure consistent with current national guidelines (Nelson et al., 2007). Consistent with previous research, increased PA participation would benefit older adults by decreasing disease and mortality risk, improving stability, decreasing fall risk and bettering health and quality of life (Blair et al., 1995; Paffenbarger et al., 1994). Of specific interest herein, PA may exert a positive effect on cognitive function in this population. Results from this study further provide a rationale for the use of objective PA measurements to strengthen future research directives. As such, use of established accelerometry methodologies will allow for more valid assessments of the potential causal relationship between PA intensity and cognitive function performance in older adults therefore should ideally be included in all PA interventions and long term evaluation of these.

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